ASTRONOMY

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Through "Monster" Eyes

Where to Look for Comet Halley

Image Intensifiers for Deep-Sky Observing

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Spiral Galaxy NGC-2997

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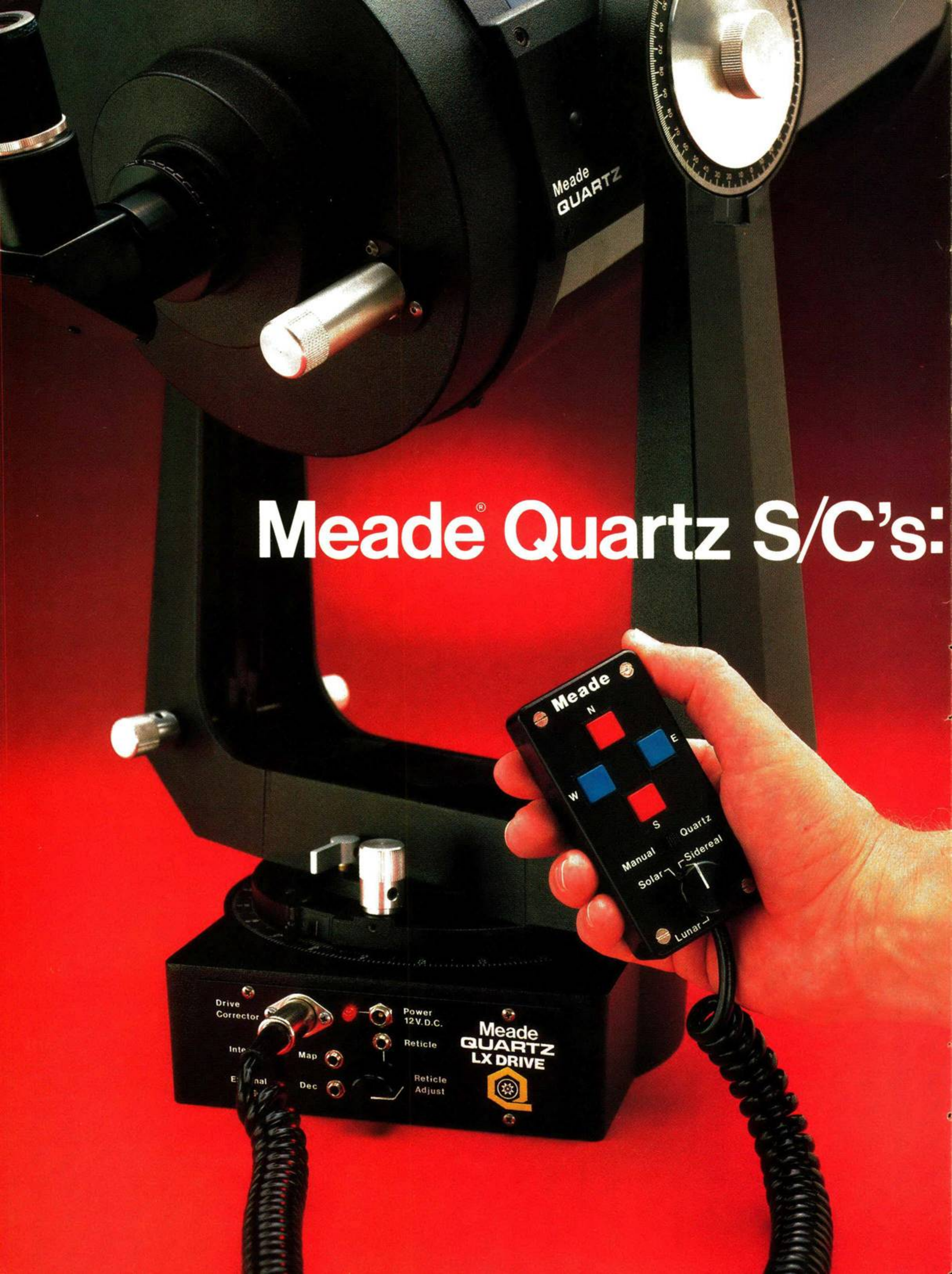
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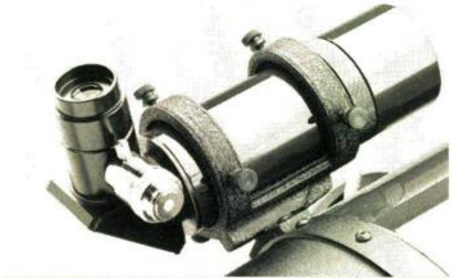

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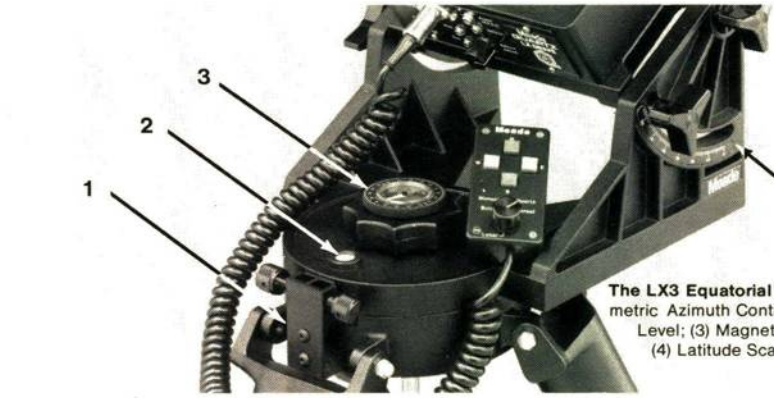

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Cover: Bright knots of gas swirl gracefully around the nucleus of a spiral galaxy. Spiral arms mark the areas where Suns like our own are being born. This month, ASTRONOMY takes you behind the scenes to unveil the plans astronomers are drawing up for a new generation of large telescopes — instruments that will dwarf the 200-inch at Palomar and push the frontiers of knowledge many times deeper into the universe. Cover and these pages: NGC-2997, photo © 1980 by the Anglo-Australian Telescope Board.

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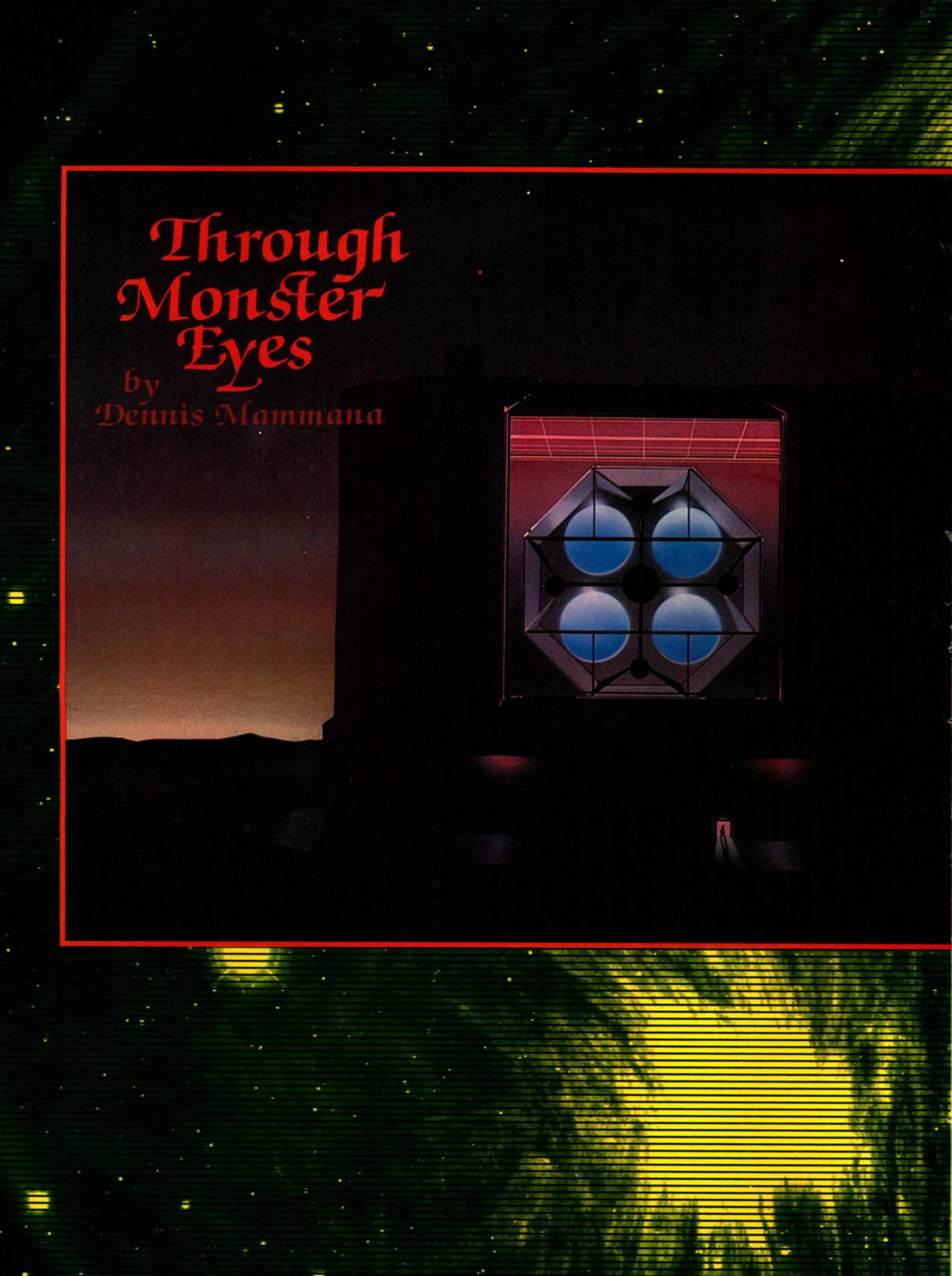
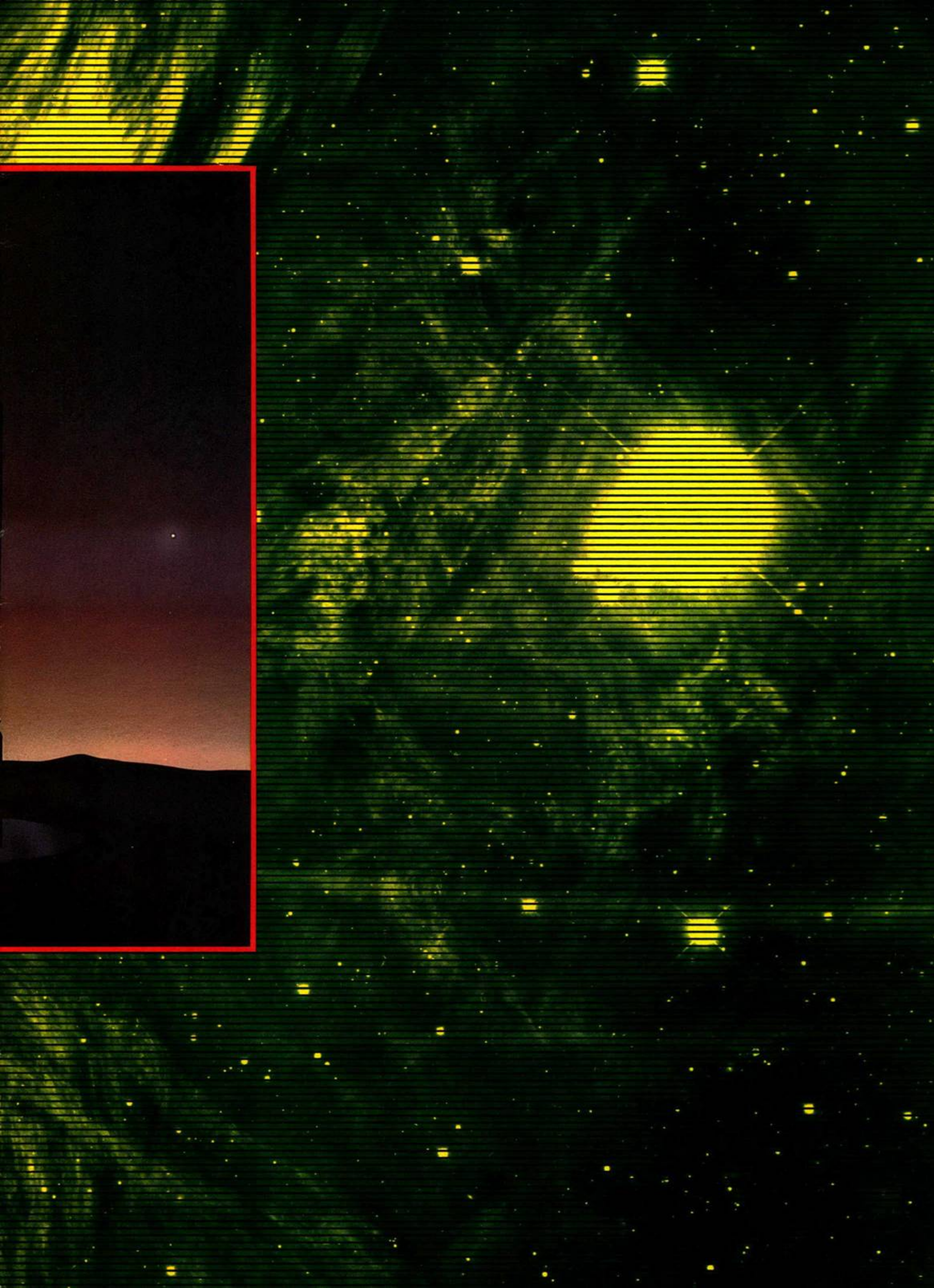
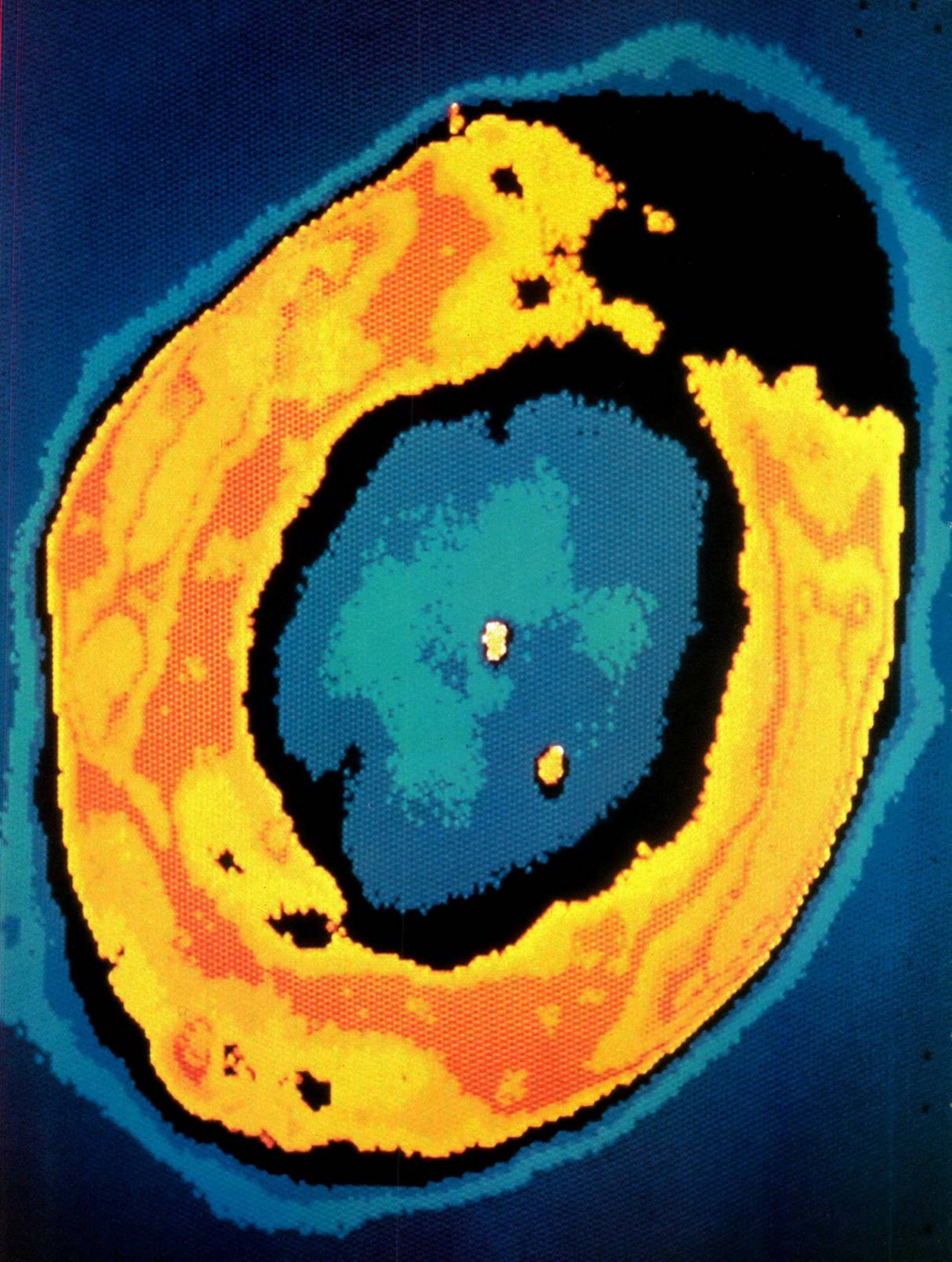
Through Monster Eyes

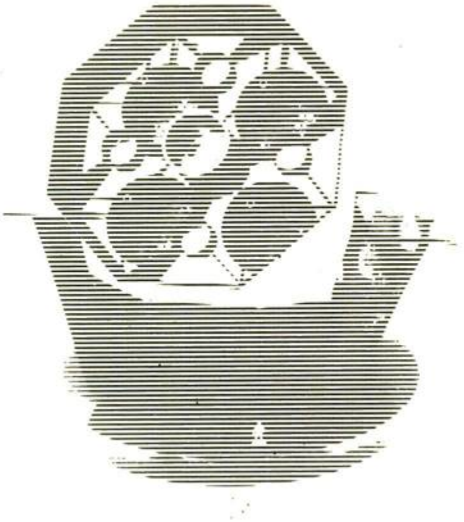
by
Dennis Mammana





Art by Brian Sullivan; KPNO photo.





Imagine a telescope so powerful that it could detect a flickering candle flame 10,000 kilometers away. Or one that could study the surface features of distant stars, detect extrasolar planets, and study a volume of space a thousand times larger than we presently can.

Astronomers are doing more than imagining. They are drawing up plans, conducting site surveys, and receiving funds to design mammoth telescopes — from a "tiny" 7-meter to a gargantuan 25-meter instrument — to extend our view into the universe.

Little more than a decade ago, such thoughts were considered foolish — technological problems combined with dramatically rising costs made such undertakings impossible. This, and the on-going problems the Soviets have had with their 6-meter telescope, led astronomers to conclude that the giant 5-meter eye of Palomar was the largest quality telescope that could ever be built on Earth.

But without larger telescopes, astronomers are staring squarely into the face of a lapse in astronomical research, the most monumental in history. "It is clear that we're going to be limited by our ability to take spectra when the Space Telescope goes up," says Roger Davies, an astronomer at Kitt Peak National Observatory. "It is also clear that in the infrared, current telescopes are limited by the size of their images. So if we want to make gains in those areas, we'll have to go to bigger telescopes."

To do so, however, is no simple task. Costs of larger telescopes increase nearly as the cube of their diameters, while construction generally requires about two years per meter of aperture. By these rules of thumb, a 10-meter instrument with four times the light-gathering power of the Palomar giant would cost eight times as much and take two decades to complete. It might even become obsolete during the early stages of its construction.

How is it possible, then, for larger telescopes ever to be constructed? Ironically, an answer to that question was offered two centuries ago by Erasmus Darwin, an English physician, botanist-poet, inventor, and natural philosopher. Darwin, who was also the grandfather of the famed naturalist, recognized that a totally new and different technology would be required. In 1779 he wrote: "Suppose twenty glasses, either lenses or concave specula [mirrors], are so placed as to throw all their images of a certain object onto one focus — there will then be one image with 20 times the brightness that one lens or speculum could produce."

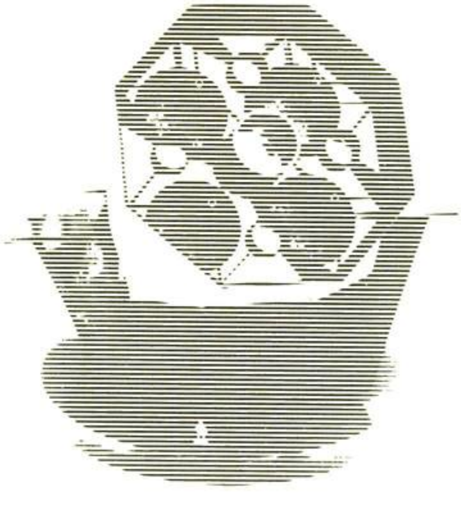
It was not until two centuries later that technology caught up with Darwin's dream. In 1979, the Multiple Mirror Telescope on Mt. Hopkins in Arizona opened its eyes on the heavens to become one of the most productive and exciting scientific instruments ever built. The MMT uses six lightweight, 1.8-meter, f/2 mirrors mounted together on a single telescope structure to gather six times the light of any one of its mirrors. An electronic "nervous system" continually monitors the optics and keeps them accurately aligned on their celestial target. The result is a telescope the length of a 1.8-meter instrument, but with the light-collecting power of a 4.5-meter. In addition, its simplified and inexpensive computer-driven altitude-azimuth mounting and unique barnlike housing perched high atop a steep mountain peak all contribute to making its overall performance among the finest in the world. With one stroke of technical genius, the MMT broke the mold set by nearly four centuries of telescope design and became a prototype for a totally new generation of large telescopes.

Inspired by the MMT's overwhelming success, astronomers around the world are employing radically new designs for monster telescopes of the future (see box on page 14). The European Southern Observatory is developing a VLT (Very Large Telescope) that will likely be constructed as an array of several 8-meter instruments. These would operate individually, or together as a tremendously powerful optical interferometer.

The Russians are hard at work on the design of a massive telescope that might use a single 25-meter primary consisting of a mosaic of many small mirrors. In addition, a number of smaller telescopes — on the order of 10 meters aperture — are being developed by researchers in England, Japan, and the Universities of California and Texas in the U.S.

Perhaps farthest along in development, however, is an ambitious project being planned by the National Optical Astronomy Observatories and the Kitt Peak National Observatory in Tucson, Arizona. It is a 15-meter

Designed as "light buckets" for spectroscopy, the new large telescopes are also capable of forming good images — witness this view of the familiar Ring Nebula (M-57) in Lyra seen through the 4.5-meter Multi-Mirror Telescope. Courtesy MMT Observatory.



instrument called the National New Technology Telescope.

The NNTT, though it seems a new and exciting idea, actually dates back at least two decades — to the founding of Kitt Peak. "In drawing up the first budget for Kitt Peak," recalls former KPNO director Aden Meinel, "we planned the first several telescopes on Kitt Peak, and then put down an X-inch telescope — the X being completely undetermined — that when the funding and technology became available, we would build as big as possible." As it happened, funding was not forthcoming and the project was quietly shelved after a few years.

But during the mid-1970s, when the need for larger telescopes was becoming painfully apparent, Kitt Peak renewed discussions about a large instrument known as the Next Generation Telescope, or NGT. It would be gigantic — an unbelievable 25 meters in diameter. "This large size was selected to gain the factor of 10 or 20 in light-gathering power and angular resolution we needed for major breakthroughs in astronomy," remarks Larry Barr, project manager of the NGT and NNTT. "Because there is no practical way you can scale up an existing telescope design to that size, it forced us to think seriously about new ways of building telescopes."

Although a number of unique proposals were made, only two survived intense scrutiny over the years. One is a multiple mirror design, similar to that on Mt. Hopkins, with four 7.5-meter mirrors mounted together on a stiff structure. The other uses a segmented-mirror concept in which 60 two-meter off-axis segments of a parabolic mirror are combined and mounted to form a single dish.

Last summer, an astronomical advisory committee recommended the multiple mirror design. The choice, according to committee chairman Robert Gehrz, came down to the design's capabilities in specific key areas: "Some of the most important science to be done with the world's largest telescope will require high spectral and spatial resolution, and the multiple mirror concept seemed, on balance, to offer outstanding and versatile performance in those applications."

Like the MMT, the NNTT's mirrors will be controlled by complex electronics to keep them aligned to within a thousandth of a millimeter. The telescope will embody significant improvements in the mounting, thermal properties of the optics, and housing compared to the Mt. Hopkins facility. It will also require the fabrication of at least four ultra-thin 7.5-meter low-expansion primary mirrors.

Though the recommendation concluded an exhaustive study that lasted several years, it was really only the beginning. "We will spend the next year and a half to two years completing the preliminary design and final proposal," Larry Barr comments. "We would like to begin construction in 1987, and all our planning to date is predicated on that possibility. If so, we'd see 'first light' through the telescope in 1992 or '93."

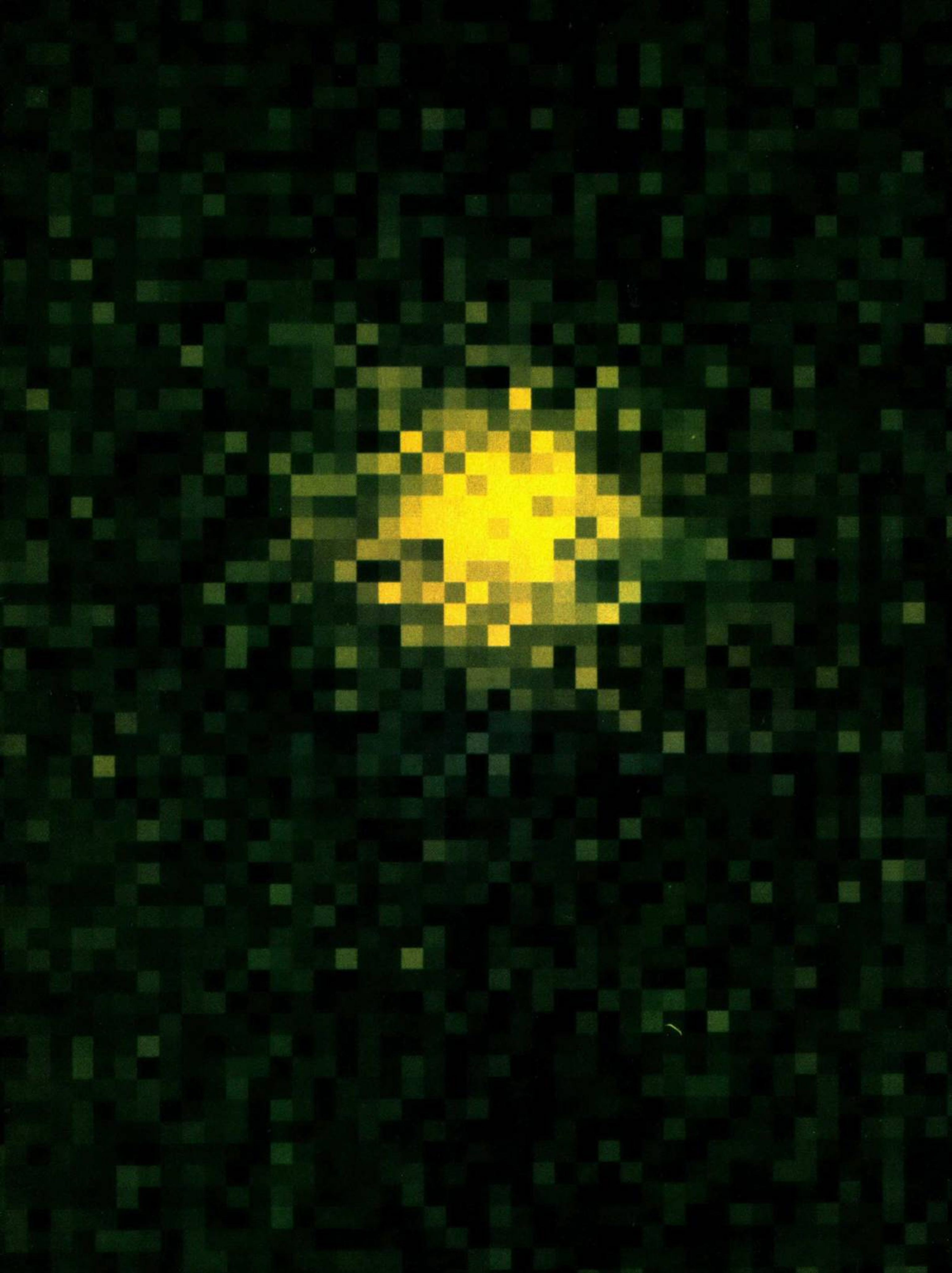
Aiming toward these goals, scientists are conducting an extensive comparative evaluation of possible sites for the instrument. Two prime sites are being considered: Mauna Kea, 4,142 meters above the Pacific Ocean on the island of Hawaii, and 3,228-meter high Mt. Graham in the Pinaleno Mountains of southeastern Arizona. The astronomers hope to have a site chosen by the summer of 1986.

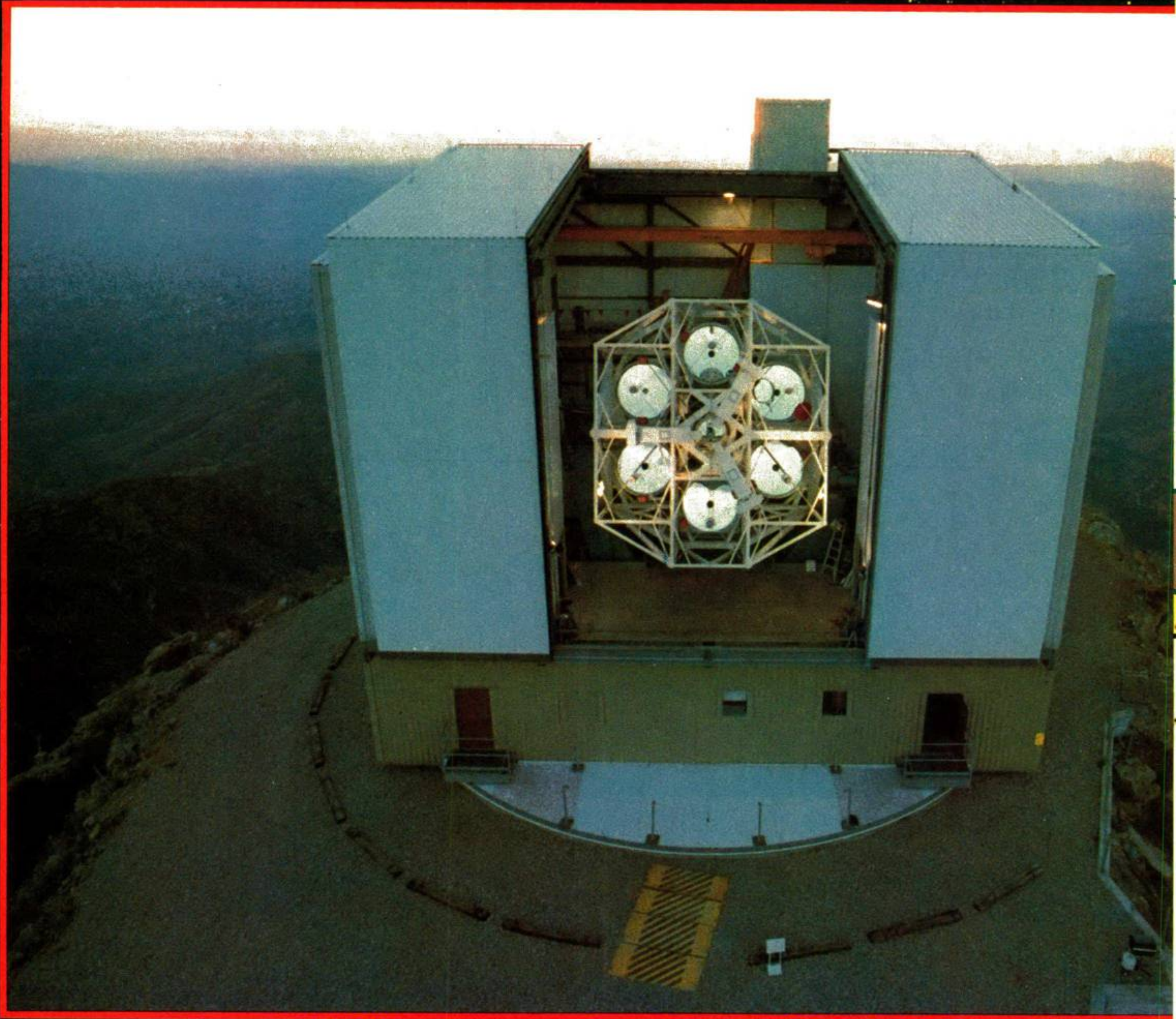
When all the work is successfully completed, little doubt should remain about the absolute superiority of the technology, optics, and site of the National New Technology Telescope.

Three years after beginning operation, the NNTT — because of its huge light-gathering area — will have collected as many photons from the universe as have been collected by all ground-based observatories throughout history. It will be able to study the faintest and farthest objects in the universe in detail never before seen. And it will do so with unprecedented sharpness. "We're looking for quarter-arcsecond imaging in the optical and infrared," says Larry Barr. "The present-day capability of most telescopes is a factor of two or three worse than that."

In addition, specialized techniques such as speckle imaging can be employed. Speckle imaging effectively removes the smearing effect of the atmosphere, thus enabling telescopes to work at the limits of their optics rather than that imposed by the turbulent atmosphere. It should provide resolutions of $\frac{1}{200}$ arc-second — about the size of a quarter-dollar seen from 1000 kilometers away.

This photo, made with the Multiple Mirror Telescope, hints at what's to come with the NNTT: Betelgeuse is a large red-giant close enough that we can glimpse its actual disk. The computer-processed image shows an asymmetry *due to a large envelope* of gas around the star. MMT photo courtesy of Jeremy Hebden and Keith Hege.

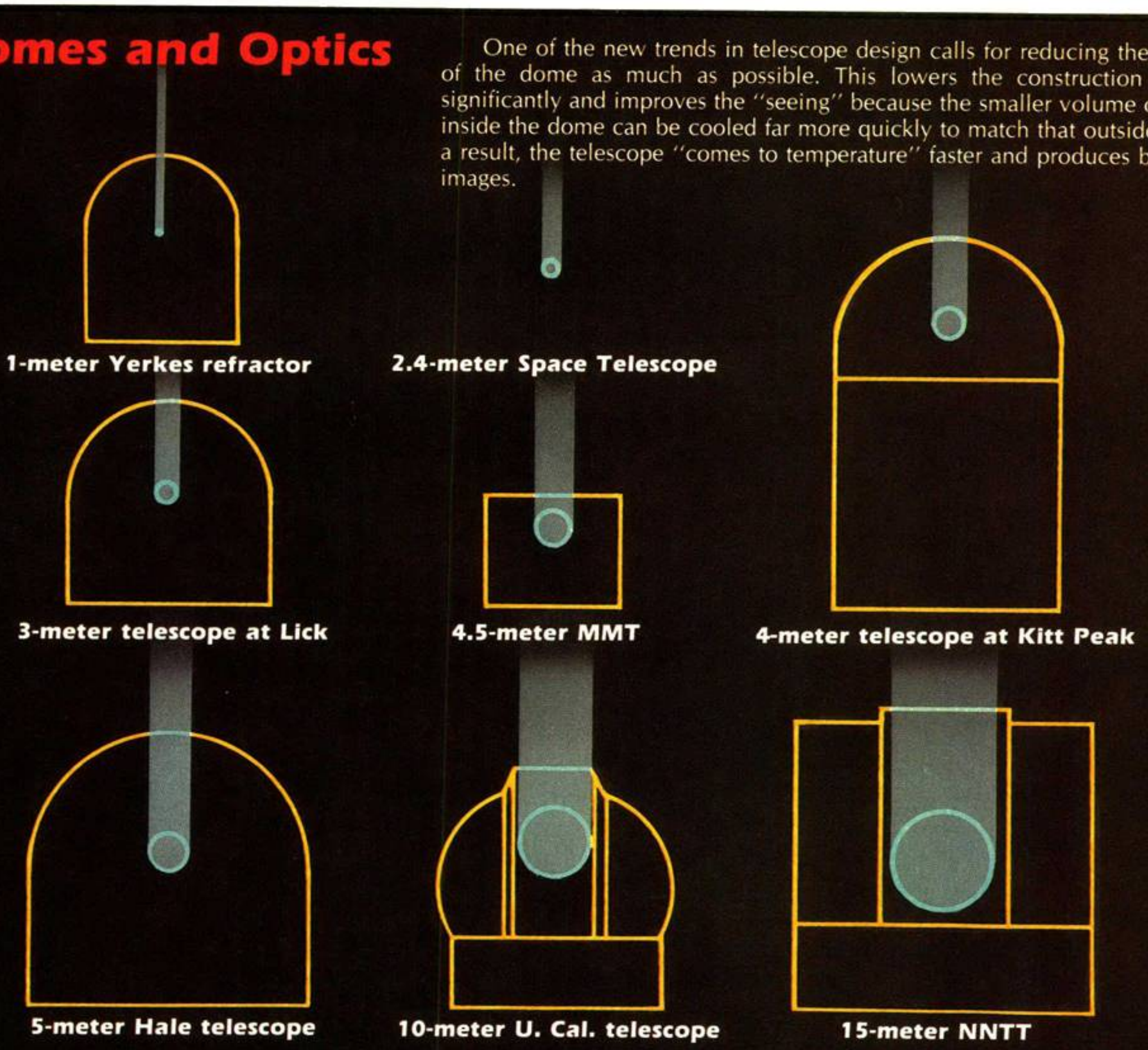




The very successful Multiple Mirror Telescope has broken the trail for a new generation of large optical telescopes. These telescopes will feature a high degree of computer control — involving every aspect from maintaining precise optical alignment to operating the detectors. Photo courtesy Smithsonian Astrophysical Observatory. Background: Spiral galaxy M-33 in Triangulum. Photo courtesy KPNO.

Domes and Optics

One of the new trends in telescope design calls for reducing the size of the dome as much as possible. This lowers the construction cost significantly and improves the "seeing" because the smaller volume of air inside the dome can be cooled far more quickly to match that outside. As a result, the telescope "comes to temperature" faster and produces better images.


1-meter Yerkes refractor
2.4-meter Space Telescope
3-meter telescope at Lick
4.5-meter MMT
4-meter telescope at Kitt Peak
5-meter Hale telescope
10-meter U. Cal. telescope
15-meter NNTT

Big Telescope Projects

The "new generation" of telescopes should revolutionize observational astronomy. Here are some of the projects now in the works or being studied:

National New Technology Telescope (NNTT)
(United States, National Optical Astronomy Observatories)
15-meter (590-inch) aperture
Multiple-mirror design with four, 7.5-meter mirrors
f/1.8 primary focal ratio
Will probably be located on Mauna Kea (Hawaii)

Ten-Meter Telescope (TMT)
(United States, University of California)
10-meter (390-inch) aperture
Segmented mirror design with 36 hexagonal mirror-sections
f/1.75 primary focal ratio
Will be located on Mauna Kea (Hawaii)

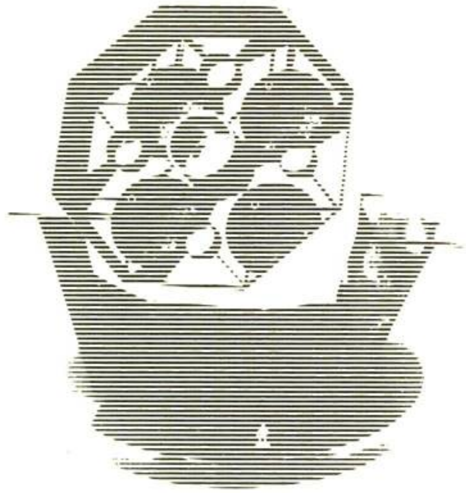
Eight-Meter Telescope
(United States, University of Arizona)
8-meter (315-inch) aperture
Segmented mirror design
f/1 primary focal ratio
Will be located on Mt. Graham (Arizona)

"The Eye of Texas"
(United States, University of Texas)
7.6-meter (300-inch) aperture
One-piece thin (6-inch thick) mirror
? f/2 primary focal ratio
Will be located on Mt. Livermore or Mt. Locke (Texas)

25-Meter Telescope
(Soviet Union, Academy of Sciences)
25-meter (985-inch) aperture
??? mirror design
??? primary focal ratio
??? location

"Seven-Meter" Telescope
(Japan)
7.5-meter (295-inch) aperture
??? mirror design
??? primary focal ratio
May be located on Mauna Kea (Hawaii)

European Southern Observatory Telescope
(eight European nations)
16-meter (630-inch) aperture
Probably an array of four, 8-meter telescopes
? f/2 primary focal ratio
May be located at La Silla (Chile)



Not only will astronomers be able to see fainter and more distant objects with sharper images, they will also be able to complete their work in record time. "For normal observations," says KPNO astronomer Roger Davies, "the gain in speed is very quick with diameter — about a factor of 14 over present-day telescopes. But in infrared observations at 10 and 20 microns, the gain in speed could be as high as 200 times." In other words, observations that now require 10 nights at the telescope could be done in less than six hours.

These remarkable features will place observing time on this instrument at a premium. "Its worth is going to be measured directly in terms of its ability to produce results for the maximum number of astronomers," notes Barr. "It follows, then, that the ability to accommodate many observers with good programs is going to be important."

Astronomers have devised several revolutionary ideas to keep the NNTT operating at nearly 100% efficiency all the time. The telescope's capability to interchange detectors and instruments rapidly will permit researchers to take advantage of excellent weather and seeing conditions as they occur. This will require a certain amount of telescope operations to be scheduled in "real time." Versatility will be fostered through remote-control observations from computer terminals in astronomers' offices around the world, enabling research to be carried out on very short notice. Astronomers will also be able to observe by proxy. They can request their data be taken when atmospheric conditions are suitable rather than waiting for their assigned observing run, which may be six months in the future.

These tremendous capabilities will be magnified even more when the NNTT teams up with the Hubble Space Telescope scheduled for launch in a few years. While the Space Telescope will excel at imaging faint distant objects — some 10 times fainter than the largest ground-based telescopes now in service — its 2.4-meter primary mirror cannot do everything. Here's where the NNTT will help. "The great complementary aspect is that with large collecting areas on the ground, you can really take spectra of these objects," says Davies. "And progress and understanding in astronomy have almost always come about when people have taken spectra, because that's what tells you about distances, internal motions, and the very nature of objects."

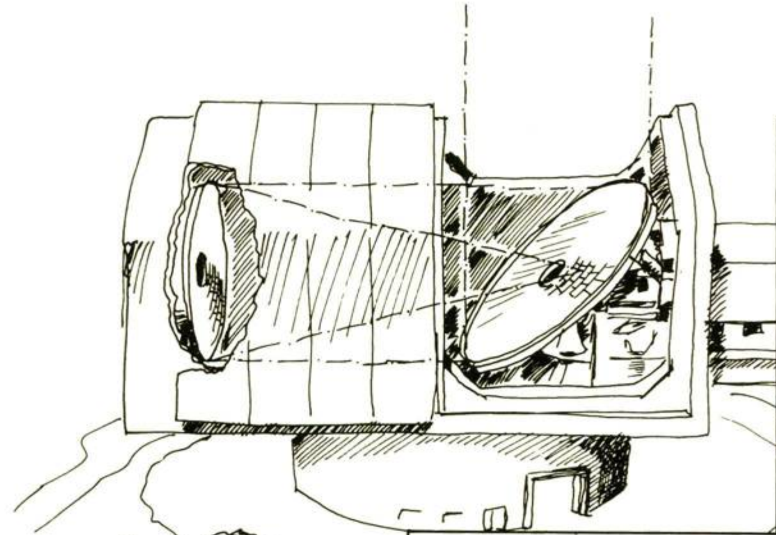
The world's astronomical community is excited about the possibilities this large new generation of telescopes is opening up. They expect major contributions will be made to our understanding of the cosmos, along with a number of startling and unexpected discoveries.

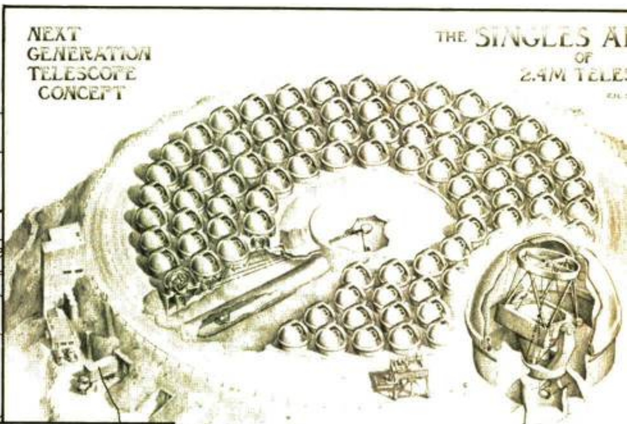
At the moment, it seems the greatest use of monster telescopes will be for work on faint galaxies and quasars, believed to be at or near the edge of the universe. Because these enigmatic objects are extremely distant, detailed work on them has been difficult to date. A large instrument will change all that. "We're going to be able to see back in time to when the universe was maybe only 10 percent of its present age," exults Davies. "And by looking at the spectra of galaxies at those early times, we're going to be able to determine what processes were at work during their formation."

Through these studies, the fate of the entire universe may also finally be understood. For decades, astronomers have been trying to learn if the expansion of the universe is slowing down — that is, if it may one day stop its expansion and begin to collapse upon itself. Supernovae in distant galaxies may prove to be effective "standard candles" for determining the sizes, distances, and rates of recession of galaxies, but such objects are out of the reach of present-day telescopes. Instruments like the NNTT will bring even extremely distant supernovae into range and may help astronomers learn the fate of the universe once and for all.

Just as distant galaxies and quasars may explain the formation of the universe, so too may globular star clusters — which populate the halo of the Milky Way — tell how our own Galaxy was born. At present, only the brightest giant stars in globulars can be studied with today's big telescopes — and these don't help much. "The problem here is that these stars have very diffuse envelopes around them, and there's a lot of convection there," Davies notes. "In fact, it's quite likely that products of nucleosynthesis have been dredged up from the interiors of the stars to their surfaces where they corrupt the spectra we get."

Telescopes like the NNTT will be able to get detailed spectra from uncontaminated dwarf stars some 100 times fainter than the giant stars and as far away as 32,000 light-years. From these, a detailed picture of the galactic halo and chemical history of our Milky Way may emerge. This could provide methods for studing similar problems in other galaxies as well.

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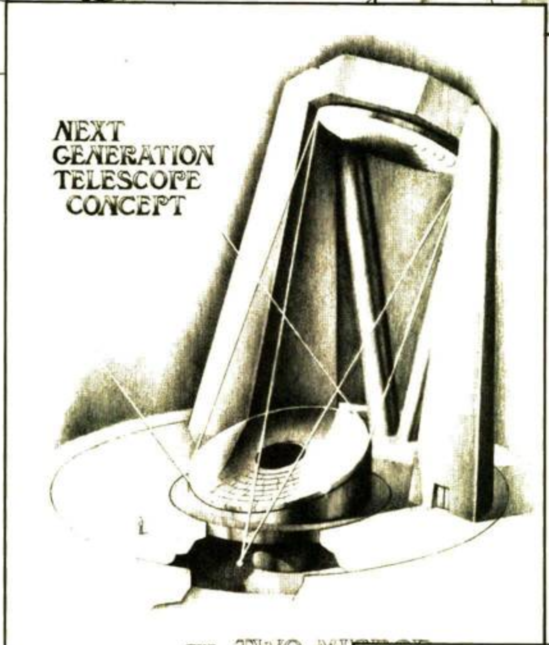
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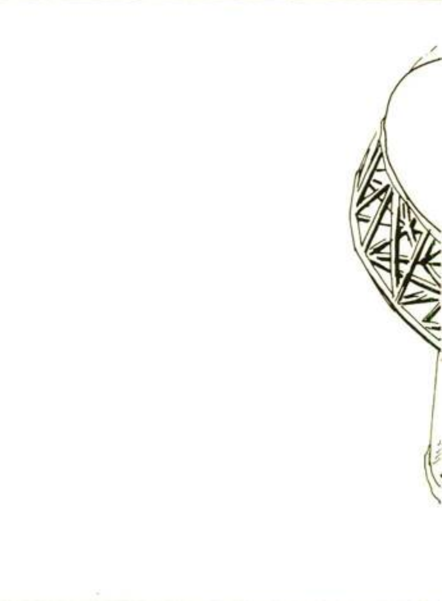
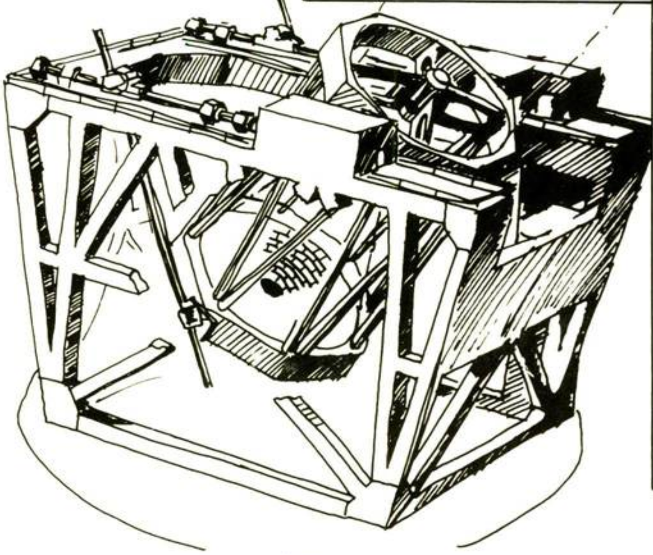
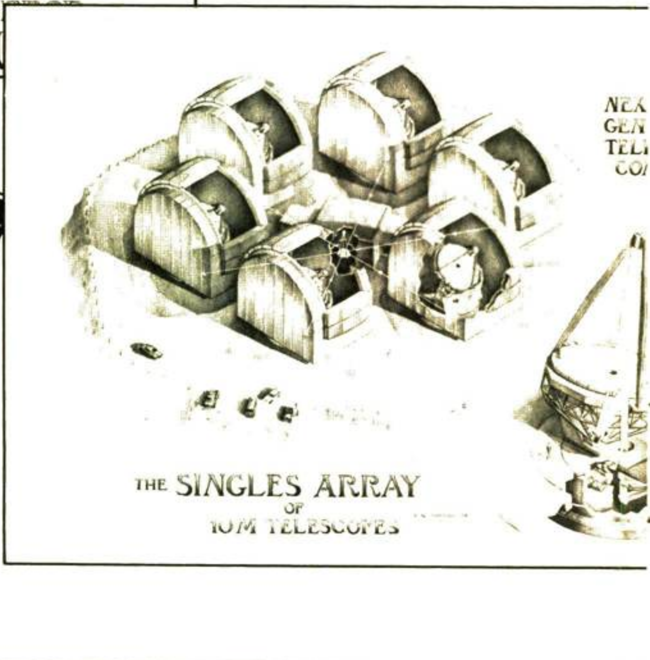


The design for the National New Technology Telescope evolved from an older concept called the "Next Generation Telescope." Shown here are some of the novel designs that were explored, and ultimately rejected, before the multiple-mirror configuration (bottom right) was chosen. Artwork by Thomas L. Hunt and R.N. Showalter; photos courtesy Kitt Peak National Observatory.

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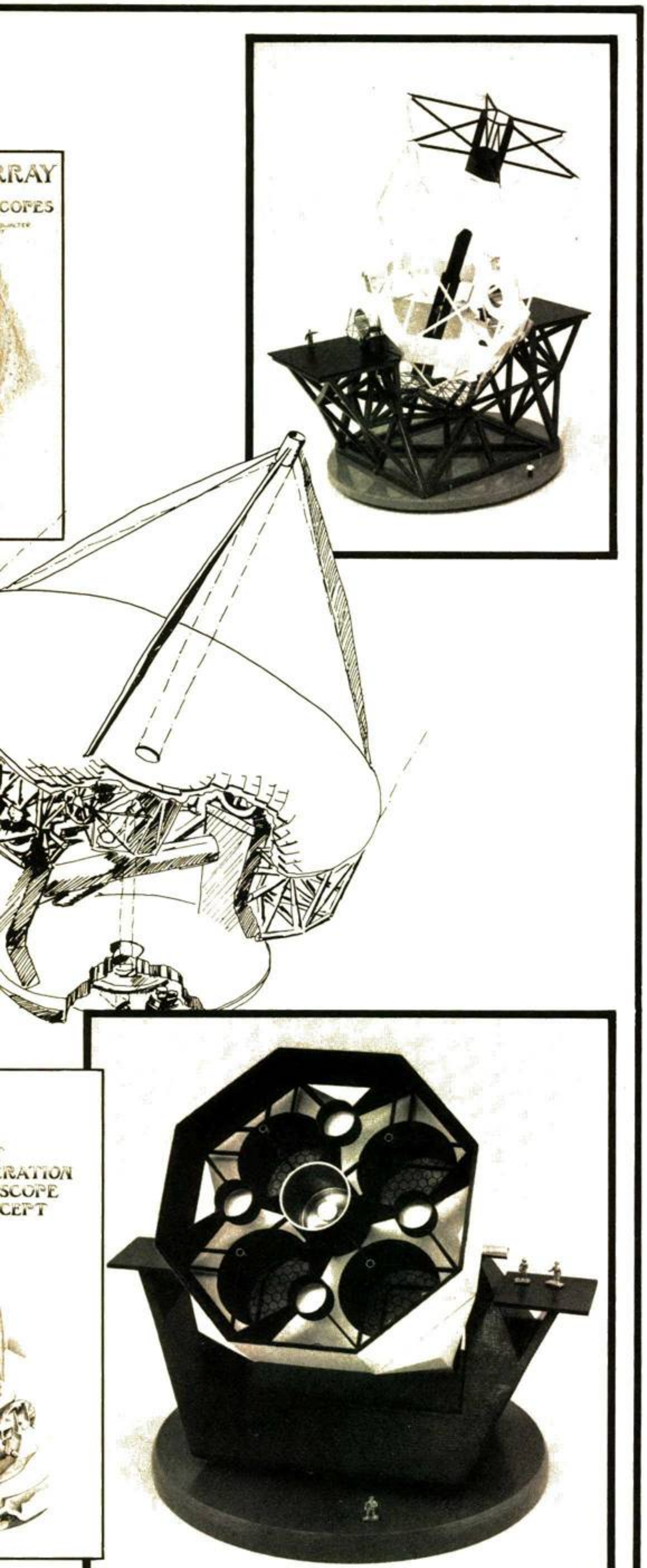
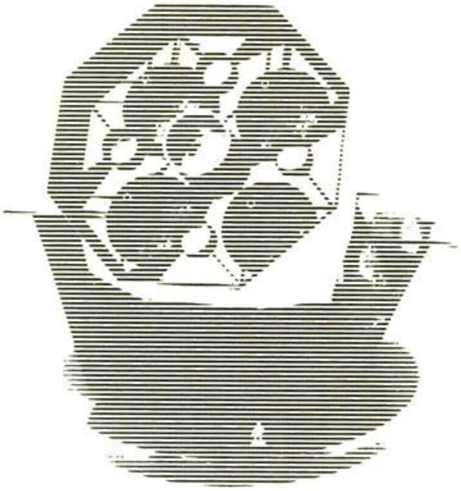




Within the disk of the Milky Way, astronomers hope to solve some of the riddles of starbirth. They have begun to map general areas in dark interstellar clouds where stars are believed to be born. But the sequence of events that leads up to a star "turning on" still remains a mystery. "The problem with star-forming regions," explains Davies, "is that they are complicated. There are lots of different stars forming, all at very different stages of evolution, all with different spectra, and it's very easy to get these things confused."

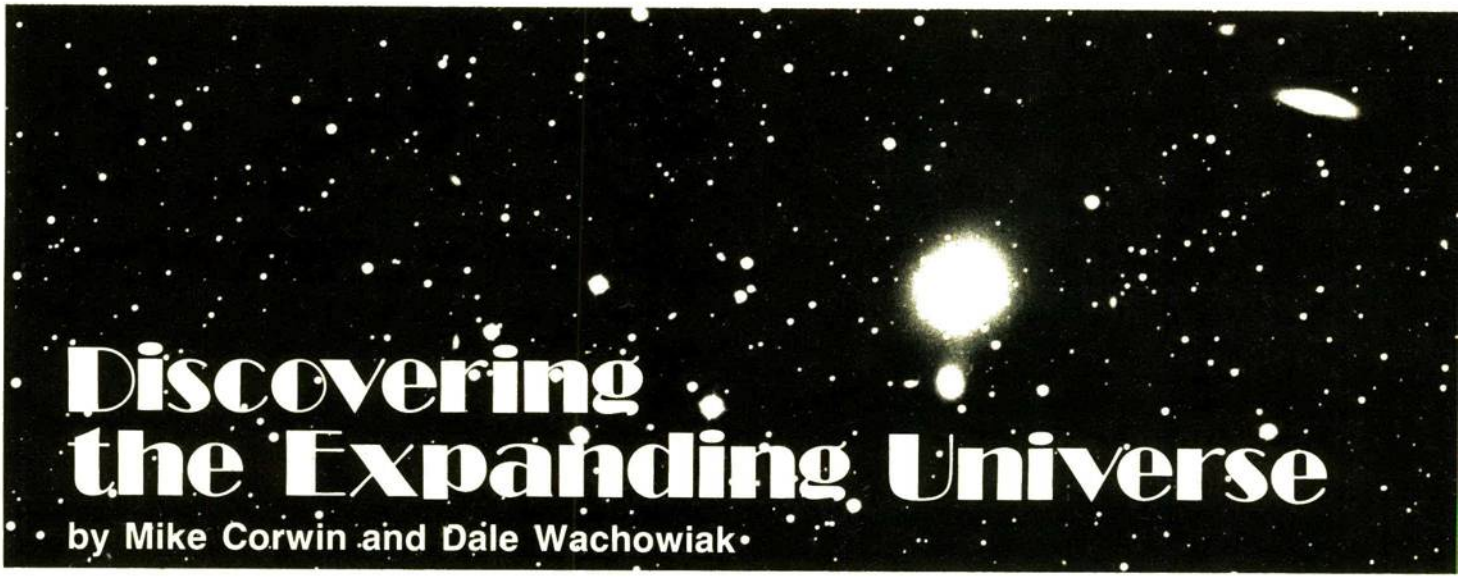
With the NNTT and the coming new-generation monster eyes, astronomers hope to see dark protostars as small as 100 astronomical units across — or only two or three times the diameter of our solar system — and less than 100,000 years old. High-resolution imaging will reveal protostellar disks, and will help unravel the complex morphology of interstellar clouds.

Closer to home, monster eyes will study the Sun's neighboring stars. Stellar granules, stellar disks, emission clouds, coronas, and chromospheres of dozens of stars will be within reach — we may even spot planets around nearby suns. This information will help us better understand energy transport systems within stars and consequently make stellar astrophysics a more exact science.

But perhaps no contribution by these large ground-based telescopes of the future will be as fascinating — and ultimately as important — as those we cannot even imagine. "Any time you have such a large jump in capabilities in a technological system, you're going to be surprised by what you discover," says Aden Meinel. "Nobody knows what lies within the range of these big telescopes. All I know is that 50 years from now astronomy is going to be totally different than it is today — but in what way I have no idea!"

We live in an exciting time. We have seen the abilities of telescopes grow a thousandfold during the last half century. It is perhaps appropriate that this century, which has contributed more than any other to our understanding of the cosmos and our place in it, will end with the greatest achievement of science and technology — monster eyes that could turn the science of astronomy totally upside-down.

Dennis Mammana is a freelance science writer and astronomy buff who lives in Tucson, Arizona.



Discovering the Expanding Universe

by Mike Corwin and Dale Wachowiak

The goal of classical astronomy was simple — to establish Earth's location in space. The transition from classical to contemporary astronomy represents a shift in emphasis from the dimensions of space to the dimension of time, a change brought about by a most amazing discovery concerning the nature of our universe. By the early 1930s, it had become clear that the amount of space in the universe actually increases with time. Regardless of where we look, the distant galaxies are all moving away from us and away from each other. The greater a galaxy's distance from us, the faster it recedes from us. The universe is expanding! This discovery changed the question astronomers worked to answer. It was no longer "What's the universe like in different places?" but rather "What is the universe like at different times?"

Anyone wishing to understand the nature of the universe must have an accurate picture of its expansion. The popular image of matter rushing out through space — the aftermath of a violent Big Bang — represents a fundamental misconception that only a look into the historical origins of the expanding universe concept can clear up.

Universes of the Mind

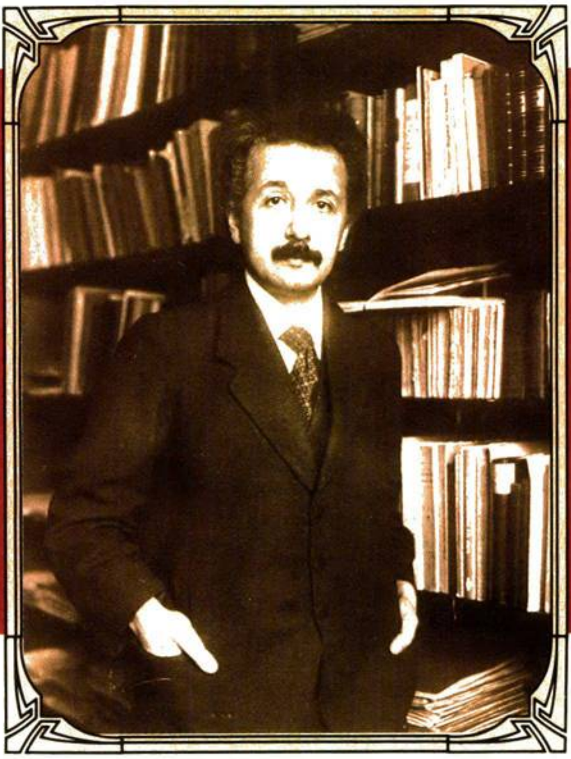
In order to tell this story, we must go to 1915 — a decade and a half before the discovery of cosmic expansion. In Germany, physicist Albert Einstein was studying the universe, as his wife would say years later, through calculations on the back of an old envelope. These calculations, based on his newly developed general theory of relativity, very nearly predicted the expansion of the universe.

In developing relativity, Einstein was guided by a deep belief in the simplicity and beauty of the physical universe. There were literally thousands of ways of expressing the physical laws of his theory, but Einstein assumed that only the simplest mathematical rule would provide a correct description of nature. Late in 1915, after years of constant effort, Einstein arrived at a version that finally met all his requirements.

What is general relativity? Put simply, it is a mathematical treatment of space-time in which gravity becomes a property of space-time itself. When Einstein attempted to apply his theory to the universe as a whole, he was surprised by one of the deductions that followed from it — the universe cannot be static, but must either expand or contract. Every astronomer Einstein consulted, however, assured him that all astronomical evidence indicated the universe is static and unchanging on the grand scale. For once in his life, Einstein lost faith in his intuition. Trusting the astronomers, he added a special term — a "fudge factor" — in the physical laws of his general theory to make the results consistent with a static universe.

Einstein called this factor the "cosmological constant." From a physical standpoint, this term corresponded to a cosmic repulsion that balanced gravitational attraction. Einstein's only reason for adding the constant was to keep the results of predictions concerning the entire universe consistent with the apparent facts. Although the cosmological constant marred the simplicity and beauty of the theory, it did produce results thought to be consistent with astronomical observations. Sixteen years later, in 1931, after observations indicated that distant galaxies are in fact receding from one another, Einstein eliminated the cosmological constant from general relativity. He called its inclusion the greatest blunder of his career.

In 1917, Einstein used his original theory to develop a mathematical model of the universe that was static (neither expanding nor contracting) and finite (a limited amount of space occupied by a limited amount of matter). Owing to the nature of space-time in his general theory, Einstein's finite universe was also unbounded — that is, it had no edges. It's important to understand this idea of an unbounded universe. Popular literature often refers to "the edge of the universe" without clarifying that this doesn't refer to a physical edge, but rather the limit of our vision. From our vantage point, the universe appears (at least on the large scale) to be the same in all directions. This property is called isotropy. Invoking the so-called Copernican principle, astronomers maintain that there is nothing special about our location in space and that isotropy must exist for observers at any arbitrary location in the universe. The universe should appear the same when viewed from any location within it. To us, of course,



Albert Einstein
1916
Adding a cosmic "fudge factor" to relativity was his greatest blunder.

Courtesy Hebrew University

our Galaxy appears to be at the center of the universe. With several earlier mistakes to bolster their conviction, however, cosmologists strongly believe that this is *not* the case.

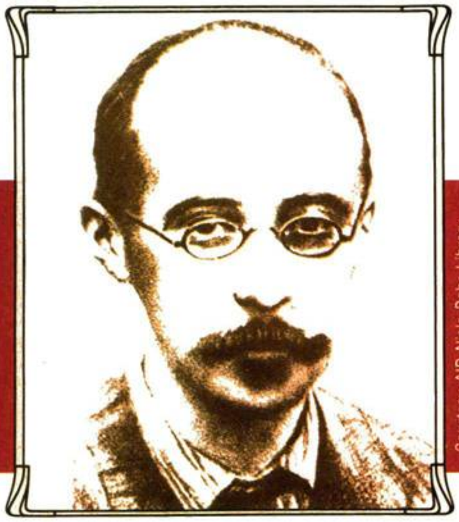
If the Copernican principle holds, then the universe is homogeneous with clusters of galaxies spread uniformly throughout space. Thus, there can be no unique center and no edge to the universe. The assumption that at any given *time* the universe must be everywhere the same is called the "cosmological principle" — it's the fundamental concept behind all modern thought on the nature of the universe. If the universe is infinite in extent, the cosmological principle is clearly possible. Even if the universe turns out to be finite (as it well may be), the cosmological principle may still remain valid. The universe can be *both* finite and unbounded!

Unfortunately, it's impossible for us to visualize a finite model of a three-dimensional universe consistent with the cosmological principle. We must make do with an analogy in two dimensions instead of three. In two dimensions, the surface of a sphere makes a finite but unbounded "universe." It curves back on itself in such a way that, in the two-dimensional space of its surface, there is no center and no edge. All observers in such a hypothetical two-dimensional universe, regardless of their location, see essentially the same things — the cosmological principle remains valid in this finite, two-dimensional universe.

Like the surface of a sphere, the geometry of space in the general theory of relativity is also curved. Although this is completely incomprehensible to our normal way of thinking, space-time curls back on itself in Einstein's 1917 model in such a way that the universe, though finite, has neither center nor outer boundary. All observers would view the universe as if they were at the center; none could look in a particular direction and see vast emptiness. This makes Einstein's model consistent with the cosmological principle.

Einstein believed his general theory (including the cosmological fudge factor) could be used as the basis for a model of the universe that is neither expanding nor contracting. This was, in fact, not true. In 1922, the Soviet mathematician Aleksandr Friedmann pointed out that the static nature of Einstein's universe was the result of an algebraic mistake — division by a quantity that in some cases could be zero. Einstein's static universe model is unstable and the slightest disturbance results in either collapse or expansion. General relativity demands a dynamic model of the cosmos. Friedmann used the general theory *sans* Einstein's cosmological constant to develop several dynamic models of his own.

Friedmann's work received little attention when it was published in the early 1920s. When Belgian cosmologist and theologian Abbe Georges Lemaitre tackled the same



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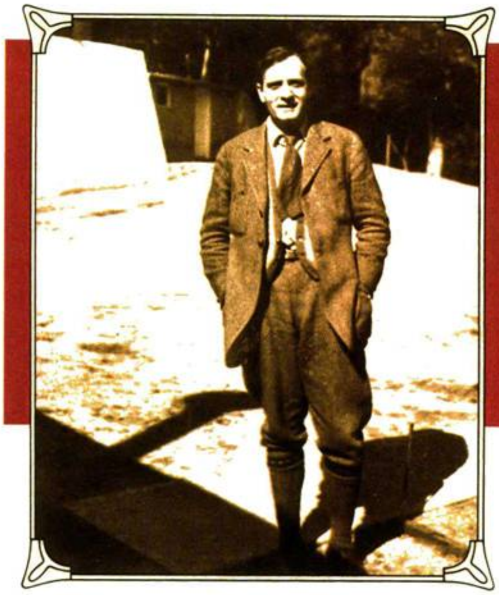
Aleksandr Friedmann, 1922
He was the first to use relativity to develop dynamic models of the universe.

Georges Lemaitre, 1927



Vesto Slipher, 1914

He was the first to find Doppler shifts in the spectra of spiral nebulae.

problem in 1927, he was completely unaware of Friedmann's results. But like Friedmann, Lemaitre discovered the seeds of a dynamic universe in Einstein's relativity theory.

Lemaitre developed an expanding model of the universe that retained the cosmological constant. He also realized that the expansion of space should have observable effects on the light we receive from very distant objects. In many of its manifestations, light behaves as if it were a wave. Light waves traveling through space that is undergoing expansion become "stretched out" — their wavelengths increase. The further the light travels (i.e., the more distant the emitting object), the greater the amount of stretch. As a result, dark line patterns characteristic of chemical elements will be found at longer wavelengths than expected; they will be shifted toward the long wavelength end of the spectrum. Because red light is at the long wavelength end of the visible spectrum, the shift is usually referred to as a redshift.

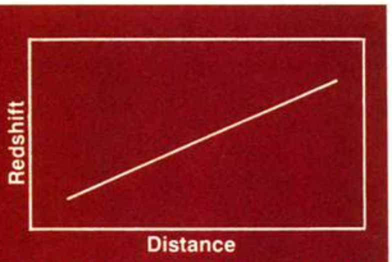
The wavelength-stretching quality of expanding space is often confused with the Doppler effect. The Doppler effect is a wavelength shift associated with the relative motion of a source and an observer. You're probably more familiar with the Doppler effect as it applies to sound waves — the difference in pitch between an approaching or receding siren — but it also applies to light. Doppler blueshifts correspond to motion toward the observer, which compresses the waves and gives them shorter, bluer wavelengths. Doppler redshifts correspond to motion away from the observer, which stretches out the waves and gives them longer, redder wavelengths.

The Doppler effect is similar, but not identical, to the effect of either a contraction (blueshift) or expansion (redshift) of space itself. With the Doppler effect the shift occurs when the light is emitted; the light then propagates through space with a constant wavelength from then on. The change in wavelength due to the expansion or contraction of space is a gradual process, occurring as light moves through the cosmos.

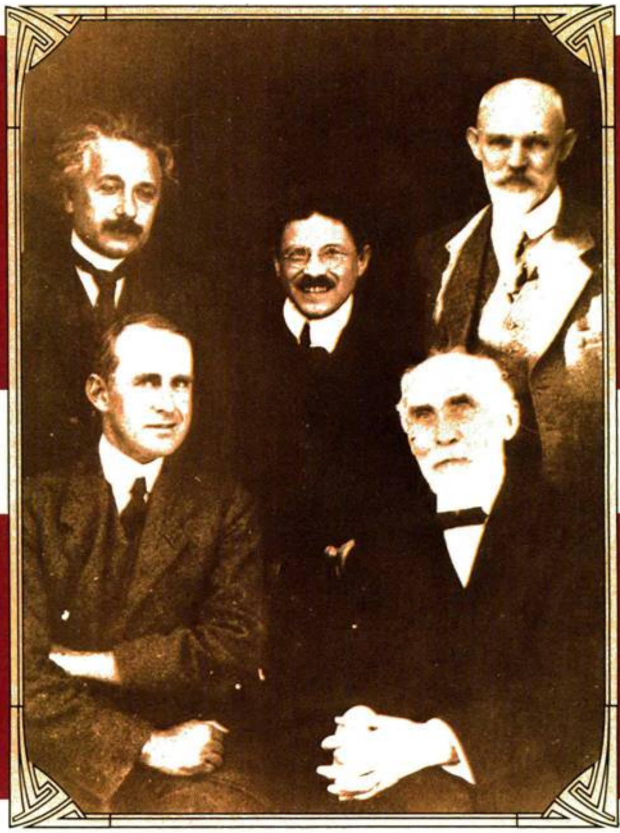
Based on his model, Lemaitre predicted that the light from distant objects would be redshifted due to the expansion of space. His model also predicted that the amount of redshift would be directly proportional to the distance. Thus, an observational test for expansion became possible.

The Universe of the Eye

While European physicists worked on the theoretical applications of general relativity to cosmology, most of the pertinent observational research was being done in the United States. In 1914, Vesto Slipher at Lowell Observatory in Arizona concluded a study of the light from objects then called spiral nebulae. (It would take another decade for astronomers to prove that these spiral nebulae were actually galaxies lying at great distances.) Slipher's study included spectra of 17 objects. In some the patterns of dark spectral lines were blueshifted, but in most they were redshifted. At the time, astronomers assumed these



Left: Edwin Hubble, 1923
Above: Hubble's relationship between redshift and distance.



Willem de Sitter, 1923

Arthur Eddington, 1923

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shifts were caused by relative motion through space — the Doppler effect.

Lemaitre was familiar with Slipher's results and acknowledged them as observational support for his model of an expanding universe. But crucial data was missing from Slipher's results — the distances to the spiral nebulae. Without this information, Slipher's results meant nothing.

In 1924, an American astronomer named Edwin Hubble used the largest telescope then in existence — the 100-inch reflector at the Mount Wilson Observatory — to identify variable stars in M-31, the Great Nebula in Andromeda. Variable stars periodically change their brightness. One type of variable, the Cepheid, shows a relationship between its true brightness and the length of time it takes to complete one cycle of variation. Knowing this, astronomers can pin down the intrinsic brightness of any Cepheid by measuring the time between successive brightness increases. Astronomers could easily determine the distance of any Cepheid by comparing its observed brightness to the brightness indicated by the period-luminosity relationship. Although astronomers had known about Cepheids for more than a decade, Hubble was the first to find one in a spiral nebula. By watching the brightness changes in M-31's Cepheids, Hubble calculated the distance to the nebula. His work revealed that the spiral nebulae were actually galaxies themselves — far beyond the boundaries of our Milky Way Galaxy. In 1929, with the distances to 18 galaxies determined, Hubble published his famous paper demonstrating the redshift in the spectrum of a distant galaxy is directly proportional to the galaxy's distance. This, of course, was exactly what Lemaitre had predicted two years earlier. Communication between the theoreticians of Europe and the astronomers of the United States was, however, so poor that Hubble was completely unaware of either Lemaitre's or Friedmann's work. He was, therefore, unfamiliar with the concept of an expanding universe.

But Hubble *was* aware of earlier theoretical work done by Dutch astronomer Willem de Sitter. In 1917, shortly after receiving a copy of Einstein's general theory, de Sitter worked out solutions for a model universe. To simplify the calculations, he assumed the universe contained no matter — an approximation of the real universe, which is mostly space anyway. The universe de Sitter created was infinite and it had a peculiar property. In de Sitter's universe, light passing between two objects at rest with respect to one another would be redshifted. This redshift was not due to either the expansion of space *or* the Doppler effect. Rather, it was associated with a mysterious slowing down of time at great distances from the observer. Further, the amount of redshift in de Sitter's model was directly proportional to the distance between the emitting and receiving objects.

Hubble knew of this "de Sitter effect" and it undoubtedly influenced his thinking. It has been suggested that a preconceived idea may have had more to do with Hubble's 1929 conclusion than his rather sketchy data (distances for only 18 galaxies, several of which showed blueshifts!). The de Sitter effect may have also played a role in Hubble's reluctance to attribute the redshift to cosmic expansion. Even long after much of the scientific community had accepted the expansion interpretation, Hubble remained reluctant. "Well, perhaps the nebulae (galaxies) are all receding in this peculiar manner," he grudgingly conceded in 1937. "But the notion is rather startling."

The person credited with recognizing Hubble's redshift-distance relationship as observational evidence of an expanding universe is Sir Arthur Eddington, the brilliant English mathematician and astronomer. Eddington, like de Sitter, was one of the first to recognize the significance

Background photo: KPNO

of Einstein's theory of relativity. In 1930, Eddington was considering the possible instability of Einstein's model universe when his research led to Lemaitre's 1927 paper on the subject.

With the news of Hubble's discovery, Eddington's enthusiasm for an expanding model of the universe became something of a cause. Through Eddington, the scientific community became aware of the works of Lemaitre and Friedmann. It was Eddington who introduced the notion that we live in an expanding universe into "mainstream cosmology" — and even to Hubble himself! In addition to his abilities as a scientist, Eddington was also a gifted writer of popular science. His 1933 book *The Expanding Universe* played a significant role in introducing modern cosmology to the nonspecialist.

Today, as in the days of Eddington, the prevailing models are expanding ones based on the general theory of relativity. This model does not mean the galaxies hurl through space, but rather that space itself is expanding. Of course, not every object in the universe is separating from every other object. Our Solar System, galaxies, and individual clusters of galaxies do not participate in this cosmic expansion — the force of gravity holds them tightly together so they are not free to expand. The dimensions of the galaxies (and everything within them) and individual clusters of galaxies do not change with time, at least not as a result of expansion. If everything were involved in the expansion, there would be no way to detect it. The concept would be meaningless.

But the distances between clusters of galaxies do increase with time. In an expanding universe, clusters of galaxies seem to be the fundamental units. Picture again, a balloon being inflated, and imagine that balloon covered with paper dots. The expanding surface represents expanding space and the dots represent clusters of galaxies. As you blow up the balloon, the size of the paper dots remains the same but the distances between them increase.

Similarly, each cluster of galaxies (like the dots on the balloon) remains approximately at rest in its own local space. At all times matter stays more or less uniformly spread throughout the entire universe. With the distances between clusters increasing due to expansion, the average density of the universe decreases with time.

Since the early 1930s, cosmologists have made many significant advances, both observational and theoretical. All tend to increase the certainty that we live in an expanding universe. However, our present understanding of the nature of the universe rests, in a most direct way, on two assumptions: 1) that the cosmological principle is correct, and 2) that the general theory of relativity is a good enough approximation of space-time to adequately account for the large-scale properties of the universe. These assumptions cannot, at least at present, be fully justified empirically; either, or both, assumptions may ultimately turn out to be false.

Theories of cosmology face a more subtle difficulty. What we normally mean by "understanding" is based to a large extent on comparison. We are accustomed to distinguishing between the accidental and essential aspects of a phenomenon by comparing it with similar phenomena. For instance, it's difficult to see how we could have come to an adequate understanding of the nature of our Sun were it not for the existence of other stars. The universe, however, is by definition unique; all of its properties must be accounted for strictly in terms of itself.

Though we must be aware of the limits of cosmology, we must not be blind to its accomplishments. It is now possible to include almost everything we know about the large-scale structure of the universe in a coherent, intellectually satisfying picture. The concept of an expanding universe plays a central role within this picture. Its inclusion in our cosmic view constitutes the most significant advance in our understanding of the universe.

Mike Corwin is an associate professor of physics at the University of North Carolina in Charlotte. He has also written Twentieth Century Physics: Remodeling the Universe, *published by Holden-Day. Dale Wachowiak is an associate professor of psychology at UNCC.*

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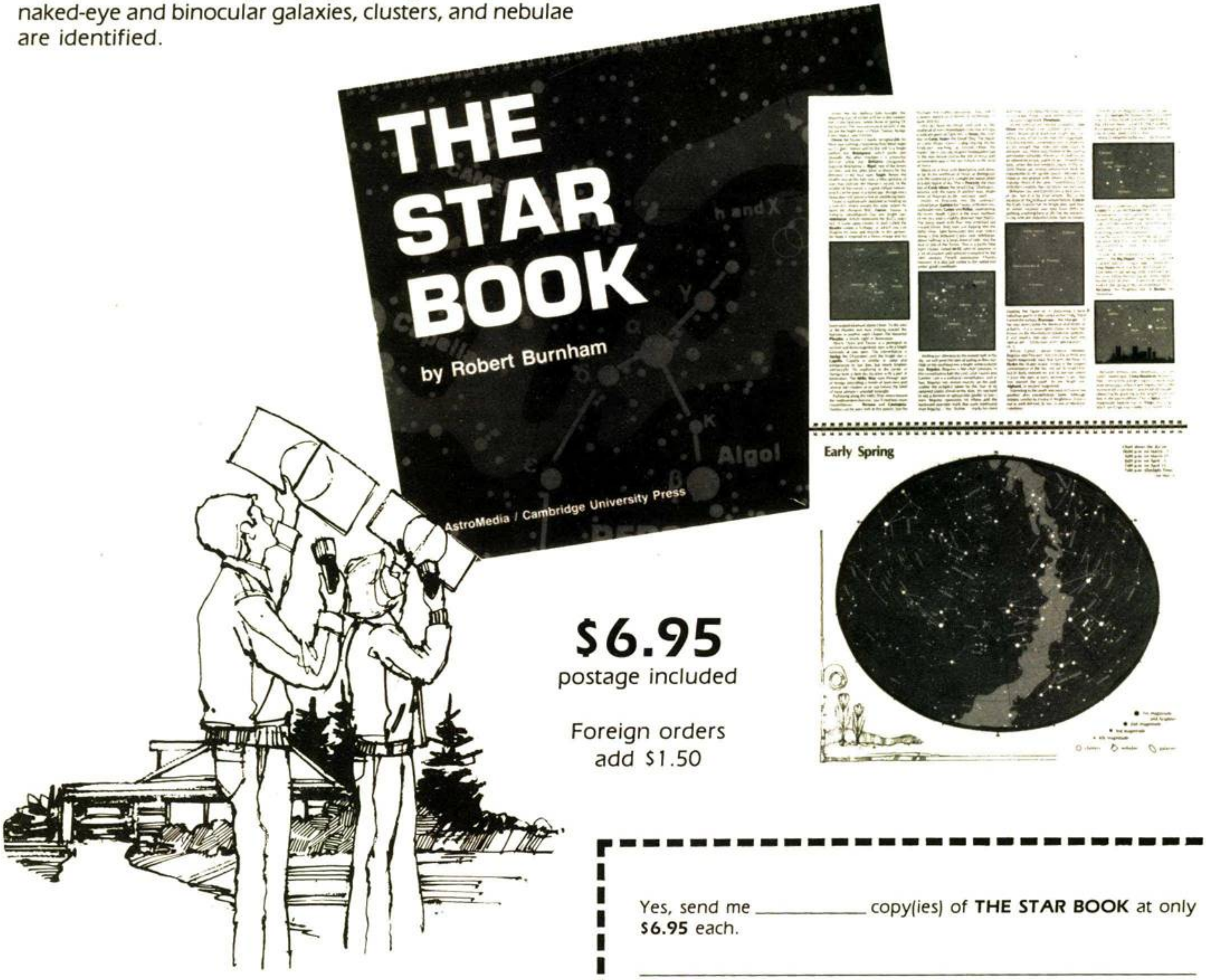

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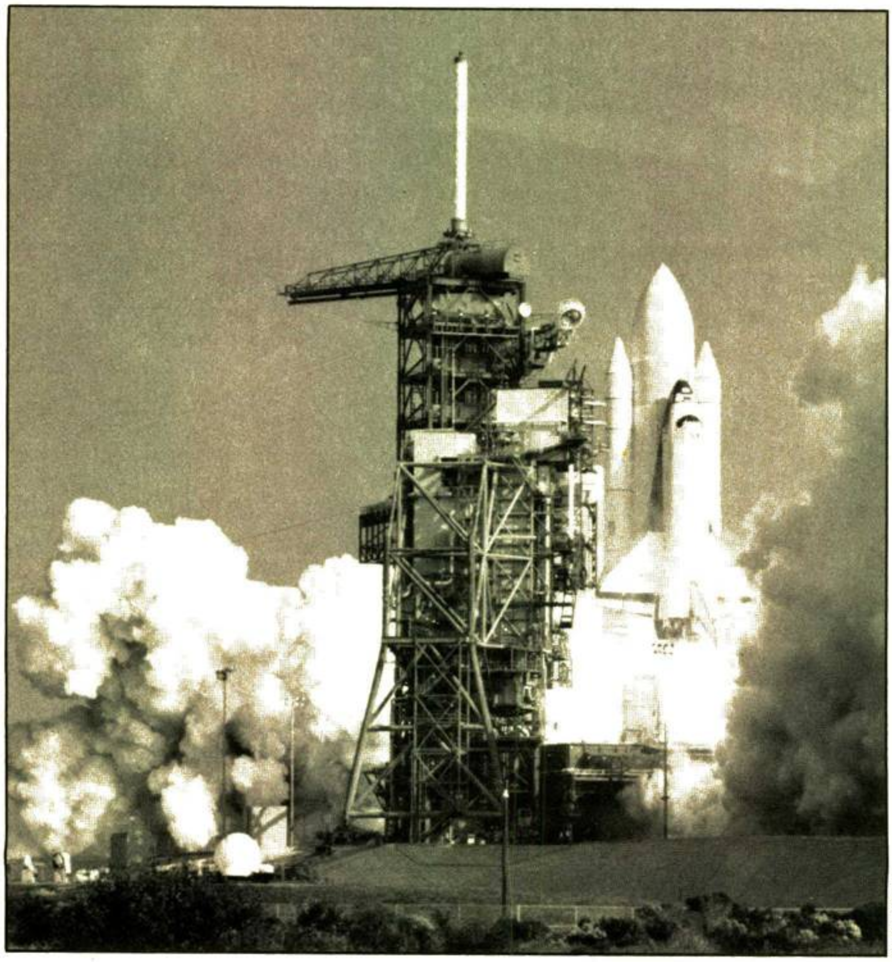
Is NASA Being Militarized?

Many of the military personnel at Johnson Space Center near Houston wear their uniforms, but some do not. There is nothing sinister about this — they're just assigned to different programs, "on loan" to various NASA organizations. I myself spent four years (1975-1979) in just such a program, after which I resigned from the Air Force to continue my Mission Control work as a civilian.

I continually hear and read expressions of public concern about the "militarization" of NASA and the Space Shuttle. Many of those comments come from people who have been long-term critics of NASA or have long ago shown their ideological or political leanings, regardless of the facts. And of course, Soviet propaganda has adopted this as a major theme.


NASA Photo

None of these criticisms can be answered in rational, factual terms. But for those people who are genuinely anxious about whether or not NASA and the Space Shuttle are gearing up for "war in space," I'd like to make some personal observations that may put the issue into a proper perspective.

At the very beginning of the Space Shuttle program, in the early 1970s, the White House decided that the Shuttle would be the national space transportation system. In other words, the Defense Department, like other space users, would be compelled to give up its stable of expendable rockets (Titan, Atlas, and Thor, for example) and make the transition to full dependence on the Space Shuttle. Contrary to current myth, this decision was forced on the unwilling military space planners — they had little eagerness to commit themselves to an unproven and potentially unreliable new technology. In 1978-79, when it appeared that the Shuttle was experiencing significant delays, the same defense planners (who had obediently drawn up plans to rely solely on the Shuttle) complained loudly that national security would suffer if the Shuttle were further delayed, so additional funding was allocated. These events gave the false impression that the Pentagon was the driving force behind the Space Shuttle. In fact, they had been compelled to burn one set of bridges behind them (the expendable boosters) and were now angry to see that the new bridge ahead of them (the Shuttle) was unfinished. Hence their public complaints.

And now that we *have* the Shuttle, is the Pentagon taking over? Critics bemoan the fact that one third of the Shuttle's missions are allocated to military payloads, but this is a groundless complaint. In fact, a proper

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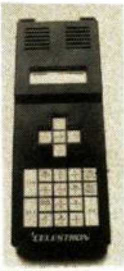

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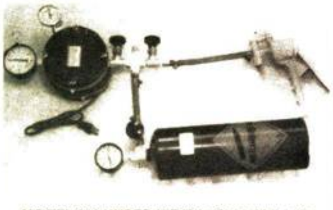

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analysis of the total space traffic of the United States shows that military activities are actually decreasing. Why? In the past, the press gave little publicity to unmanned military space launches. But everyone pays more attention when missions are scheduled for the Shuttle.

Look at the statistics. From 1978 to 1980, 60 American satellites were launched successfully. Of these, 27 (or 45%) were for the Pentagon, 19 were for commercial applications (primarily communications and weather observation), and 14 were for scientific research. Of 41 Shuttle missions scheduled from 1984 to 1986, about eight will be devoted to military payloads (less than 20%), with some additional military launches from expendable boosters. But by 1987-88, when practically *all* military space launches will be aboard the Shuttle, only 14 of the 42 planned payloads will be military — exactly one third. With that trend, the military percentage of total national space traffic will be decreasing!

Similar statistics can contradict the often-heard suggestion that the Shuttle launch site at Vandenberg Air Force Base in California is to be the home of "military shuttles." There is a geographical, not military, rationale for construction of the base: the Florida launch site cannot be used for orbits with inclinations higher than 57°, so another site with open ocean to the south is required to reach near-polar orbits.

While it is true that such high-inclination satellites are primarily military in nature, they are not overwhelmingly so. Again, past activity can put this in perspective. In the period from 1978 to 1983, 53 satellites were sent into space aboard expendable boosters from Vandenberg AFB. Of these, 27 (51%) were launched for military purposes, 15 (28%) for communications or weather applications and 11 (21%) for scientific research. It's reasonable to assume a similar percentage of cargo aboard the Shuttle — which hardly supports the image of Vandenberg as "the military space port."

In the same period, 60 launches were made from Florida. They break down into 37% military (almost entirely bound for geosynchronous equatorial orbits), 51% applications (same destination), and 12% scientific. We can assume that the Space Shuttle will be carrying traffic at about the same ratio, with slightly fewer military missions and slightly more scientific ones.

What about the claims that military personnel are taking over at NASA? In my experience, the military officers in Mission Control are performing spaceflight duties, not military duties, — and this helps to support the Space Shuttle program in general, as well as to train the officers for control of military missions in the future. There were hundreds of Air Force officers in Houston during the Apollo program for the same reasons — but there were no signs that Apollo was "militarized."

The same goes for anxiety over high-level NASA officials with military connections, such as James Abrahamson, head of the Space Shuttle program (and an Air Force Major General) and Hans Mark, deputy director of NASA (and former Secretary of the Air Force). Abrahamson is a former astronaut whose expertise is in management of large technological projects. Nobody disputes that he has done an excellent job and that NASA is lucky to have a man of his caliber. Another Air Force general, Sam Phillips, was head of the Apollo program in the 1960s, but again, Apollo was not militarized. As for Hans Mark, he went to the Pentagon for a few years after a long career in universities and at NASA. He was former head of the Ames Research Center in California, which controlled the Pioneer probes to Jupiter and Saturn.

Among the general public, many fear "war in space" — a few actually desire it. But the Space Shuttle provides no basis for either reaction. Published accounts of combat spaceships have little connection with reality. The Shuttle cannot be used as an anti-satellite weapon since it is too damage-sensitive and takes too long to prepare for launch. Putting "laser cannon" aboard it is also a nitwit idea, as is the oft-repeated nonsense about placing thermonuclear warheads into orbit. Besides being illegal, such an activity makes no practical military sense. But the ideas fly much higher and farther than the Space Shuttle ever could.

Such facts as these, I'm afraid, have little relevance to the continuing uproar about "space militarization." The motivations for it are not technological, but political and ideological.

James E. Oberg
Dickinson, TX

A Reply to "The Tragedy of the American Space Program"

November's Forum featured an article by Don Lago entitled "The Tragedy of the American Space Program." Ignoring some of the rough spots in his history and sociology, Mr. Lago's piece can possibly be called important. His words should be set in stone: "We explore not to make our lives more comfortable, but to make them more meaningful." No doubt about it. The quest for increasing comfort and conveniences spirals into degeneracy; the search for knowledge is an endless adventure.

A word about a word. Lago often uses "practical," but perhaps he could have chosen a term of more taxonomic value. Practical can connote pragmatism or, more narrowly in commercial culture, the value of conversion rather than the value of use. A brilliant man I once knew told me that the French reduce matters of money to matters of principle because they feel comfortable arguing for their principles. Americans, it seems, reduce matters of principle to matters of money because they find it easier to count cash.

I cannot imagine how Lago deduced that "Soviet ideology place(s) higher value on the pursuit of pure knowledge." Only two points need to be offered in refutation: a) They have a far more restricted economic potential than we do, and b) the good old doctrine of "socialist realism" — bane of everything from abstract art to genetics. If in fact the U.S.S.R. is socialist, it is a grey, plodding, left-wing babbittry.

In addition to the general apathy of a "So, what else is new?" species, our space program has three disparate elements of opposition: the artistic intelligentsia, the liberals, and the conservatives.

As much as author Lago rightly abhors selling the space program on the merits of its marketplace "spin-offs," it might be the sort of propaganda necessary to deal with conservatives. Many of them seem to regard society as a giant commercial enterprise with mercantile values. At an extreme, this philosophy is expressed as, "If it doesn't make somebody money in a capital intensive milieu, get rid of it." To such folks, the charm of electronic innovation, frying pans, and Tang is an undeniable motivation. Then, too, there is always the enticement of big federal contracts.

Conservatives can usually be relied on to point out the waste of hard-earned tax dollars. Somehow, tax dollars are by their very definition "hard-earned." Party affiliation aside, William Proxmire can be assigned to this category. For example, he dismissed the search for extraterrestrial life as just another boondoggle until Carl Sagan intervened with a more enlightened word. Ronald Reagan, apart

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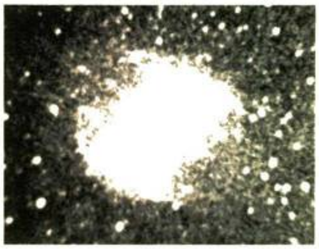

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from his recent space station proposal, can hardly be called the spacefarer's friend. Interestingly enough, conservatives can be full of surprises. Spiro Agnew was the samurai who waged incessant war on "radiclibs," but when interviewed the day of Apollo 11's launch, he declared we should prepare an expedition to Mars!

Talk about the Right Stuff.

Six years ago, I attended a community discussion group on something or other. In the row before me sat a handsome, middle-aged woman whose whole universe seemed to revolve around publicly-supported day-care centers. When the convener asked where public money should be going today, she opined: "Well, we don't need NASA."

That brings us to the liberals.

Until a few years ago — when it became electorally prudent to do so — liberals did not speak much of Hard-Earned Tax Dollars. It was a matter of "priorities." The contrail of Apollo 11 had hardly disappeared when I read a magazine article by Kenneth Delano about how the space program did not really take from the poor. The same year Mark S. Geston pointed out with measurable contempt that whereas liberal critics of Apollo always point to the $5 billion per annum it cost, they routinely shy away from real drains on the economy like La Cosa Nostra. Nothing like a soft target. One might add that much of that Mafia action was and is eagerly contributed by the poor.

Roy Abernathy, at the Cape for the big occasion with a deputation from the Poor People's campaign, had the nerve to say that as he watched the bird fly he momentarily forgot the plight of the poor in America. Damning with faint praise. A socialist friend of mine was unsympathetic to my coverage on Apollo 13's fate, dismissing all news coverage as "bread and circuses." I was not savvy enough to point out that our society has developed far more effective ways of diverting the masses from their plight. There remains no doubt that 15 years ago, the space program caught some of the bile directed at the Indo-China adventure. As warriors against poverty saw the wealth of this nation sink into blood-hued rice paddies, there was always "that lousy Moon program."

A whimsical comment was made by a television commentator while we awaited an Apollo launching. He said . . . was it Frank Reynolds? . . . that if some current critics of the space program had *their* way, Queen Isabella would have given her jewels to the poor instead of Cristofo Colombo. How much impact would that really have had on their society? I might add to those penetrating remarks by extending a cold war analogy dating back to the 15th century, to please the Militaristic Right. Space would surely have lost the New World Race to Portugal or England.

Now what about the intelligentsia? One might argue that in America, land of the No Nonsense Practical Man (there's that word again), they are of no consequence. We should hesitate, however, before indulging in such off-handed pejorative comments. To launch a discussion on the role of the learned class in American perceptions and policy-making would be tiresome and beyond this paper. Let's be content to say that it is non-zero. Enough idealism surfaces here and there to make our republic an attractive place despite its middle-aged spread. Mr. Lago's reference to Norman Mailer is apt and the effect of *A Fire on the Moon*, given Mailer's literary standing, is nothing to shrug off. The same notion can be multiplied a hundredfold when regarding the lesser stars in our intellectual constellations. A more succinct version of the "literary/sociological view" is found in Clifton Fadiman's introduction to the 1958 edition of *The Martian Chronicles*. Writing at the very dawn of the space age, Fadiman already knew it was going to be absolute dreck, using terms like "assaults on the Moon," "psychosis," and "lunacy."

> ***Cosmic exploration is one of the very few activities we can call the "real business of humanity."***

Interestingly enough, H.G. Wells saw all of the above in the 1930s. His screenplay for *The Shape of Things to Come* had the artistic intelligentsia creating quite a debate in the 21st century. The focal point for controversy was a Moon shot and one of the principals went on television, urging people to give up their maddening drive in quest of adventure and knowledge. The alternative was an artistic existence — living for aesthetics. This rendering of effete short-sightedness came 35 years before Henry "Scoop" Jackson used the other edge of the sword. When the supersonic transport was scuttled, he sought to mollify disappointed constituents in Washington by blaming the forces of "anti-technology." As a skillful statesman, he could see a good straw man a light-year off.

After all that, can we say anything positive? Yes.

Before Sputnik, this country was preparing plans for space. The decade of the '70s was not kind to us — politically or economically. It may seem that there is a loss of big dreams, but it is probably temporary — some small sign is a 1982 poll showing Americans wanting a more active space program. We astrophiles must remember that such public opinion is remarkable considering the esoteric nature of the proposed adventure.

Even as we regret its demise, let us remember what Apollo did. Although brief, Apollo was an "unnatural" acceleration of our capacity to penetrate the cosmos. It was a magnificent *tour de force* of '60s technology and public will that, beyond a certain point, had nowhere to go. Future generations will marvel that men dared assault interplanetary space in such machines. True, we did not get full value, but when we look at the Shuttle and the lamentably wasted Skylab, we see the way space flight was meant to come about — the von Braun model. We are not, in a sense, ready to enjoy the Moon.

Like Lord Tennyson, we will "dip" into the future. In taking a long-range view, we find comfort while dealing with the loss of momentum that we deplore. Cosmic exploration is one of the very few activities we can call the "real business of humanity."

A century hence, historians will look back upon the mid-90s as the time when mankind gained a handhold on bigger and better things — computers and rocket probes. They, like Mr. Lago, will shake their heads at what took so long . . . at the hesitation. Hindsight will be 20/20. "If they had *really* wanted to, they could have mounted an expedition to Mars by 1990."

A millennium hence — and remember that predicting the far future is easier than predicting the next decade — historians will take an even more dismissive view of Earthly affairs. An entire school will argue that the Industrial Revolution, from around 1750 to 1950, was the necessary evolutionary preparation for manifest destiny of the world. They will analyze the post-renaissance development of the modern state as having no other ultimate purpose than social organization necessary for the Leap. The bloated empires of Russia, Britain, and the United States will be viewed by this school as the societies we needed in order to create the technology, information bases, and economies that brought on the space age.

One last item is worth mentioning. By that millennium hence, a long monograph with a short footnote may record that two inconsequential writers in a popular journal of the times spent a lot of words lamenting the state of the American space program.

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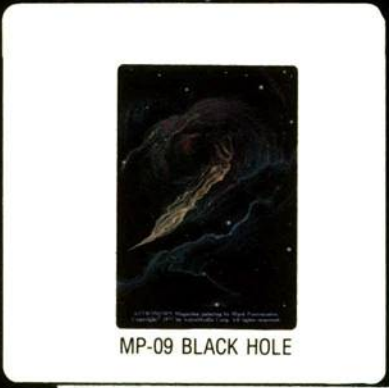

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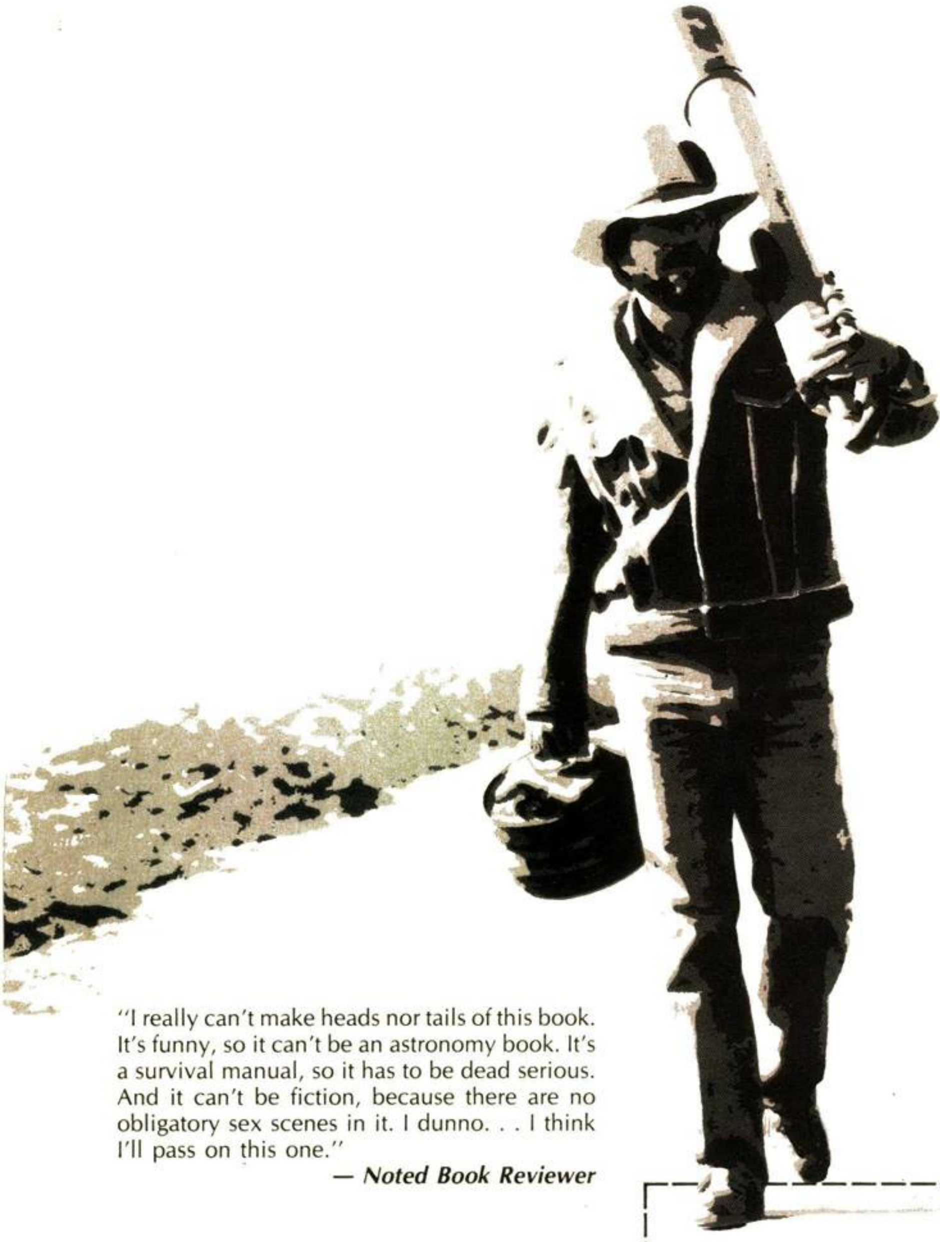

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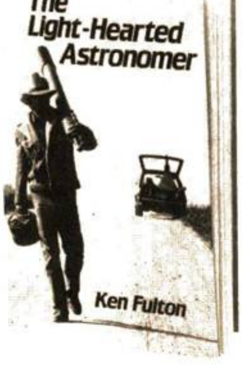

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ASTRONOMY
In Focus

Star Colors

Sir / The ancient Greeks called Sirius "the red star," even though it is currently bluish-white. Since a star like Sirius probably can't change color in a few thousand years, this dilemma might be explained by Earth's axial precession. Sirius has precessed northward for the last 10,000 years. Using geometry, we find that Sirius currently reaches a maximum altitude of 38° as seen from Athens (altitude 37° north). In 500 B.C., however, it culminated in Athenian skies at 27° elevation. Near 3,000 B.C., it was 16° high. It was unobservable before 6,500 B.C.

Since stars are reddened by Earth's atmosphere when they are within 8° or so of the horizon, Sirius could well have appeared reddish to the Greeks circa 4,700 B.C. — because of Earth's atmosphere, however, not Sirius' physical behavior.

Walker Vaning
San Rafael, CA

Sir / Fred Schaaf's article in the June 1984 issue sparked some old memories of observing star colors. When I was a child, I lived in a suburban location without light-pollution and was fascinated by the stars. I used to stargaze as much as possible, and I vividly remember seeing colors in some of the brighter stars.

Later, as I had less time to observe and moved from my old site, I could no longer see stars as anything but white. After realizing this, I began trying to find colorful stars — but it took much searching. Now I see most stars as white, but here and there can pick out reds, oranges, and subtle blues. Perhaps one day I shall again see the dramatic colors I remember from my childhood days of observing.

Lawrence D. Sanders
Vacaville, CA

— If you're having trouble seeing star colors, why not try looking at the stars with binoculars or a small telescope? These can provide enough light for the retina to detect color rather easily in many objects. Remember that scintillation, caused by gazing though lots of atmosphere, does weird things to star colors — so look at stars when they're placed high up in the sky.

Low-Elevation Viewing

Sir / I don't know if this is a world record, but it is certainly the North American record for low-elevation viewing. We took this shot at Bennetts Long Camp in Death Valley, California, in January 1983. The elevation here is approximately 252 feet *below* sea level.

Appropriately enough, the large snow-capped mountain in the background is Telescope Peak, 10,000 feet high.

Randy Krupp and
Gordon Dayton
Beverly Hills, CA

First and Last Appearances

Sir / On page 42 of the October ASTRONOMY, Fred Schaaf asks: "What is the last day you can detect Saturn?" I know this really has no scientific value, but it *is* great fun.

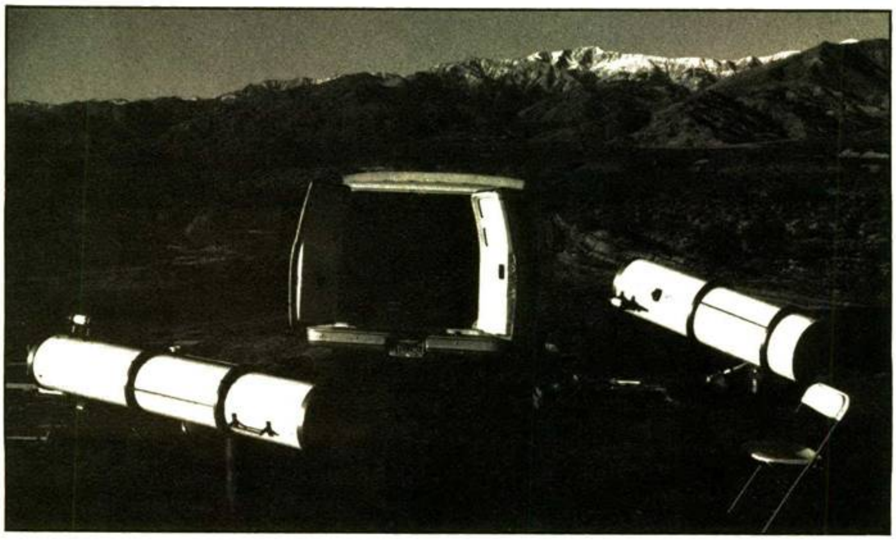
Living in Romford, 20 miles due east of London and hence 51½° north latitude, I always watch first-magnitude stars to see how late I can see them, either with the naked eye or my 16x50 binoculars.

This year, I glimpsed Sirius on 30th April. Unfortunately, May 1st and 2nd were cloudy and I lost her. Last year, I followed Arcturus down to an amazing December 1st low in the northwest and, a little earlier, Antares got lost in daylight on October 12th.

Also, I can scan the northern horizon on February evenings with my 16x50s and pick out a very elusive Vega. Without optical aid, Vega disappears by February.

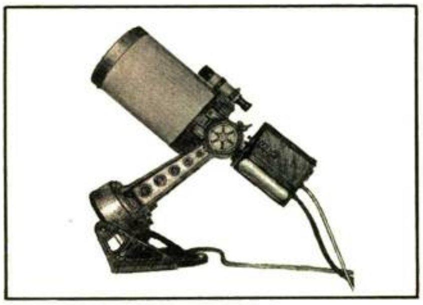
Could anyone tell me how late you can see Antares and Sirius from, say, Los Angeles, Houston, etc.?

Danny Kain
Romford, Essex, England



Video Doings

Sir / I just read Peter Manly's article on video astronomy (November 1984). About 10 years ago, I tried almost the same thing with my C-8. A video engineer friend of mine had gotten hold of an Ampex black-and-white camera and we cobbled together a Celestron-to-"C"-mount adapter. Instead of using counterweights as shown in Manly's photo, we rearranged the fork mount.



The sketch shows how the scope looked after being demounted from its fork, reversed, and bolted back onto the fork with the fork "thrown around" 180°. This maneuver not only reduces the total weight that the drive has to move (by eliminating the counterweights), but also allows the camera to swing through the fork.

A few years later when video cameras and videotape recorders became more available, I used the same arrangement to videotape lunar and planetary objects. (Near O'Hare Airport, deep-sky objects are a bit much to hope for!) The arrangement works fine and I have some very nice videotapes to show for the effort.

Patrick J. O'Connor
Chicago, IL

Soviet Moon Program

Sir / I think Peter Pesavento erred in his "Soviets to the Moon," December 1984 issue.

Pesavento attributes more significance to Alexei Leonov's 10-minute space walk in 1965 than it probably deserves. True, it was a first and Leonov did use a self-contained life-support backpack, but his space walk was not exactly the start of a flurry of Soviet extravehicular activity aimed at lunar exploration. The next Soviet EVA was not until 1969, when crew members transferred between the docked Soyuz 4 and 5 spacecraft, and the next spacewalk after that was not until 1977 during Soyuz 26.

Pesavento also asserts the Luna 15 spacecraft was a "stripped down" version of the Soviet manned lunar craft. To substantiate this, he compares Luna's 6,500 lb. weight with a figure he gives as the "descent weight" of the U.S. lunar module: 11,600 lbs. In actuality, the descent weight of the American lunar module was in the 32,000 lb. range. It's reasonable to assume that a Soviet manned lunar lander would have to weigh as much as the American LM — and many early Soviet spacecraft were actually much heavier than their U.S. counterparts. Since Luna 15's weight *was* similar to that of later Soviet robot lunar landers, it's most probable that it was a lunar sample return attempt meant to upstage the Apollo 11 manned lunar landing — an attempt that failed.

The call sign "Diamond" that Pesavento attributes to the aborted Soviet manned circumlunar flight in 1968 had actually been used already on the Voskhod 2 flight in 1965. The Soviets were in the practice of assigning unique call signs to all their manned flights, so it's unlikely that they would re-use one.

While most Western analysts of the Soviet space effort would agree with Pesavento that ample evidence exists that the Zond unmanned flights were leading directly to manned circumlunar flights by the Russians — and that plans for subsequent manned lunar landings were in the works — the nature of those landing plans is still surrounded by a great deal of mystery.

ASTRONOMY readers interested in finding out more about the Soviet lunar effort should read James Oberg's book *Red Star in Orbit*. Another source is the U.S. Senate's report *Soviet Space Programs: 1976-80*, available from the Government Printing Office bookstore.

Arthur J. Stoppe
Westmont, NJ

Ooops!

On page 8 of the November issue, the interacting galaxies NGC-5426 and NGC-5427 were mistakenly identified as NGC-5432 and NGC-5435.

Behind the Scenes

Waiting for Halley

Who will be the first amateur astronomer to photograph Comet Halley on its return? And who will be the first to see it? As the comet's motion carries it toward the Sun and it grows brighter, many telescopes will be turned toward it, many rolls of film exposed, and many hopeful eyes will scan for something still too faint to see.

Then suddenly it will be there — a tiny speck on a 35mm negative; an all-but-invisible glimmer on someone's retina. It won't really matter who sees it first — soon thousands and eventually millions will view Comet Halley — but then there's more than a little glory attached to the recovery.

Professional astronomers have been monitoring Halley for over two years using the world's largest telescopes and ultra-sensitive detectors. Last September, however, Tsutomu Seki photographed Halley with the 24-inch reflector at Geisei Observatory, signaling that the comet now lies within the reach of normal techniques. At magnitude 20.5, it wasn't bright.

For the comet seekers, this month we're pleased to bring you a chart for finding Halley — if at all possible — before the comet is lost in evening twilight this year. By "blinking" pictures taken of the expected location of the comet on different nights, you should be able to detect it as a faint speck of light if it's within the range of your telescope.

For computer buffs, we present a program to predict Halley's position. You input the date and the program calculates the 1950 coordinates and magnitude of the comet. Originally written for the Timex/Sinclair ZX-80, the program will run on all but the smallest machines. As with any program, the burden of translating our generic BASIC program into your machine's BASIC is up to you — we simply can't debug the program for the dozens of dialects of this computer language now in use.

But by the time you read this, HALLEY.BAS may be available in quite a few BASIC dialects. Just days after posting the program in Compuserve's Public Access area, I noticed that translations of the program for the C-64 and Pet were also posted. Compacting the program output by removing a few PRINT statements gets it running on the Radio Shack Model 100 and NEC-8201 notebook computers just beautifully.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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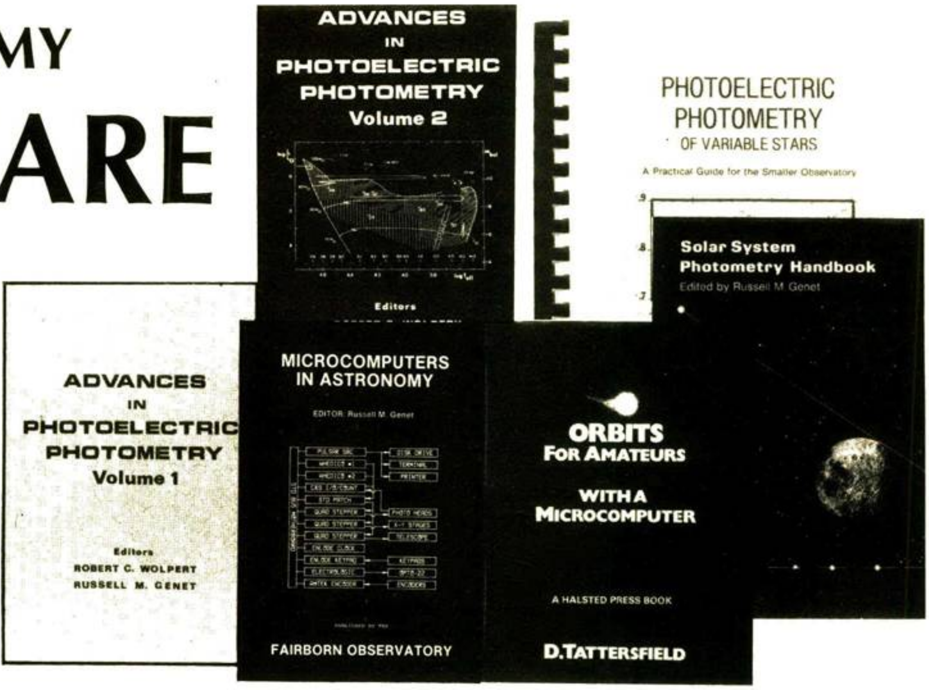
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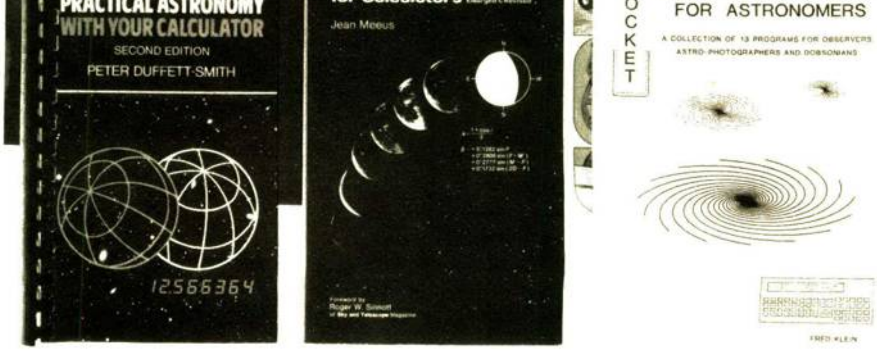
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Find Halley's Comet by Blinking

by
Ben Mayer

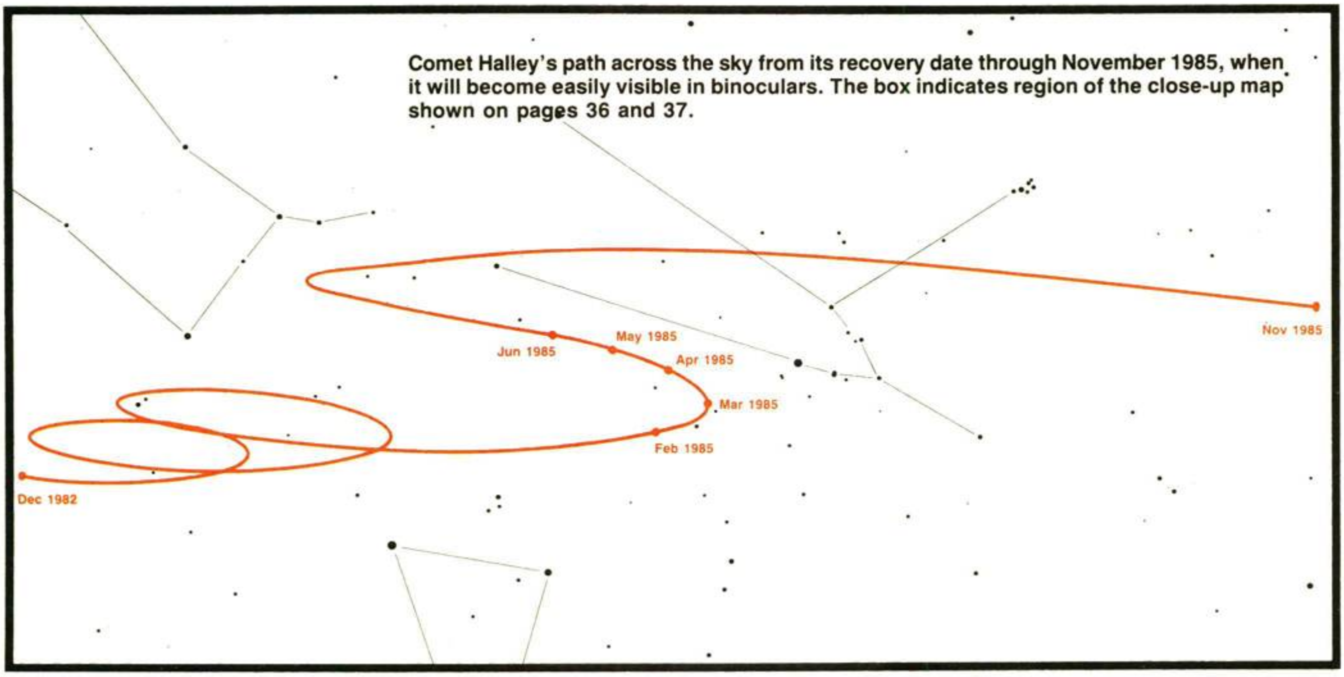
Although professional astronomers used the Hale telescope to photograph Halley's Comet in late 1982, backyard astronomers have not glimpsed this famous object for nearly 75 years. How can you find Comet Halley on the earliest possible night? There is a method, called "blinking," which will enable you to start your quest tonight or on the next clear, moonless night. Even if you can't see this historic comet, you may be able to photograph the areas where you know it will be on any given evening and then blink to find Halley.

Calibrating the System

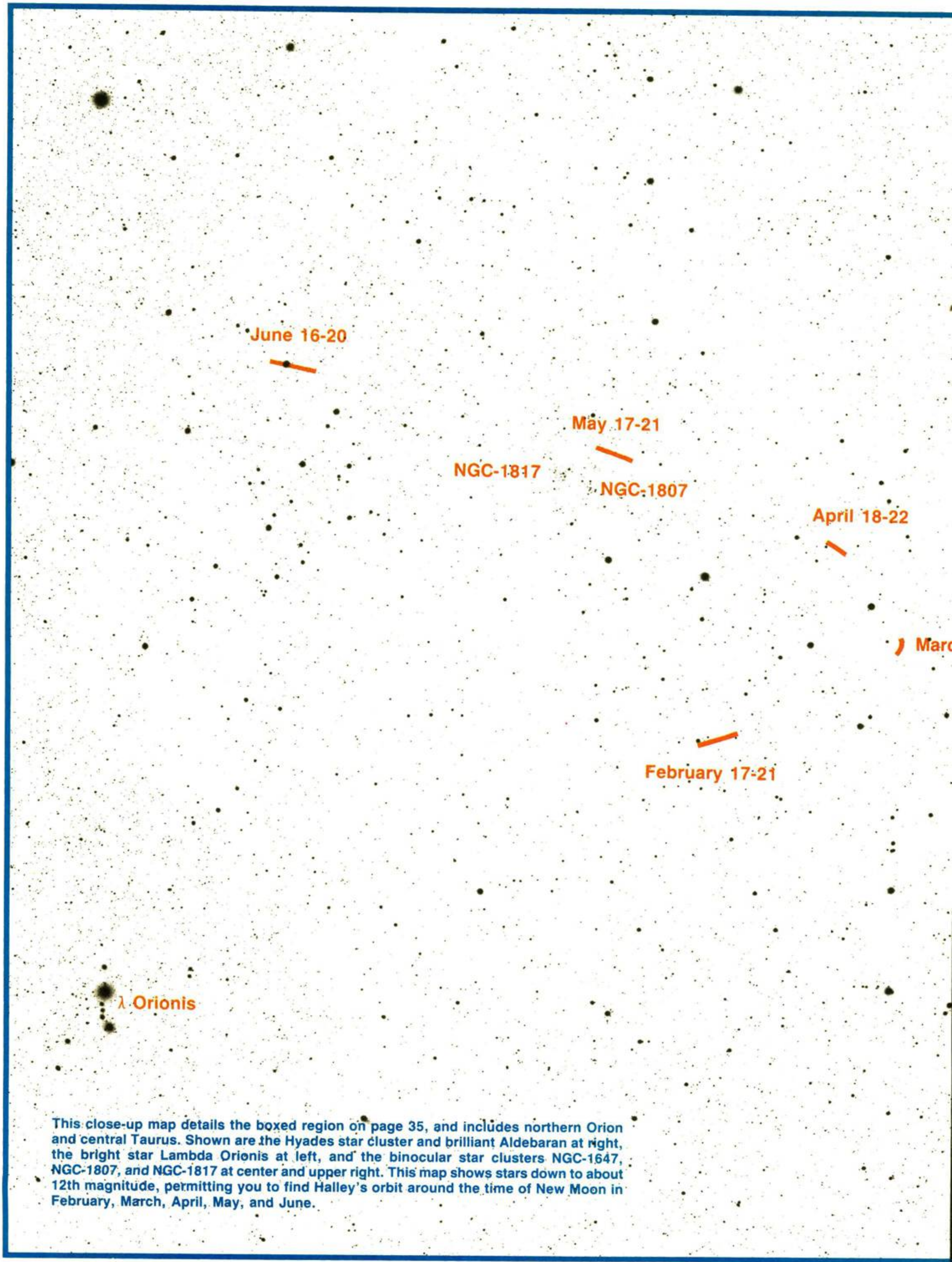
Recovering Halley is simple in principle. It consists of three separate operations, which together will permit you to find the little speck of light representing Halley's Comet on your photographic negative. First, you must calibrate your telescope/camera system to determine the faintest stars you can photograph. To do this, make an exposure of the globular star cluster NGC-2419 in Lynx. By comparing your negative or an enlargement from it to the chart on page 38, you can determine your system's limits to 0.1 of a magnitude. The exposure should be the same exposure you plan to use when photographing the comet so your calibration will hold true. Whether you work with an 8-inch Schmidt camera using gas-hypered 2415 Technical Pan film or a homebuilt 14-inch Newtonian with color film pushed from 1600 to 3200 ISO, you can establish the potential reach of your equipment by calibrating it (and even if you never photograph the comet, you'll know your telescope, camera, and film's limiting magnitude). Let's consider an example: With an 8-inch SCT operating at f/10, a 45-minute exposure on 103a-F emulsion penetrates to slightly fainter than 17th magnitude. By looking in the *Astronomical Almanac* you will see that the comet should reach magnitude 16.2 by early March. Based on this, you might want to start photographing the areas in which Halley will lie during that time.

Making the "Data" Slides

After determining when you should attempt to photograph Comet Halley, plan to make exposures of fields the comet will lie in during New Moons: around February 19th, March 21st, or April 20th, depending on your system's penetration. To recover Halley before this autumn, start early — by April the comet will be lost in the evening twilight. Seek a location for your photography as far away from city lights as possible. Select the equipment and type of film you plan to use throughout your search. In order for all photographs to be closely identical for later comparison, record the site, film emulsions, exposure times, seeing conditions, and other pertinent variables in a log.



Comet Halley's path across the sky from its recovery date through November 1985, when it will become easily visible in binoculars. The box indicates region of the close-up map shown on pages 36 and 37.


June 16-20
May 17-21
NGC-1817
NGC-1807
April 18-22
Marc
February 17-21
λ Orionis

This close-up map details the boxed region on page 35, and includes northern Orion and central Taurus. Shown are the Hyades star cluster and brilliant Aldebaran at right, the bright star Lambda Orionis at left, and the binocular star clusters NGC-1647, NGC-1807, and NGC-1817 at center and upper right. This map shows stars down to about 12th magnitude, permitting you to find Halley's orbit around the time of New Moon in February, March, April, May, and June.

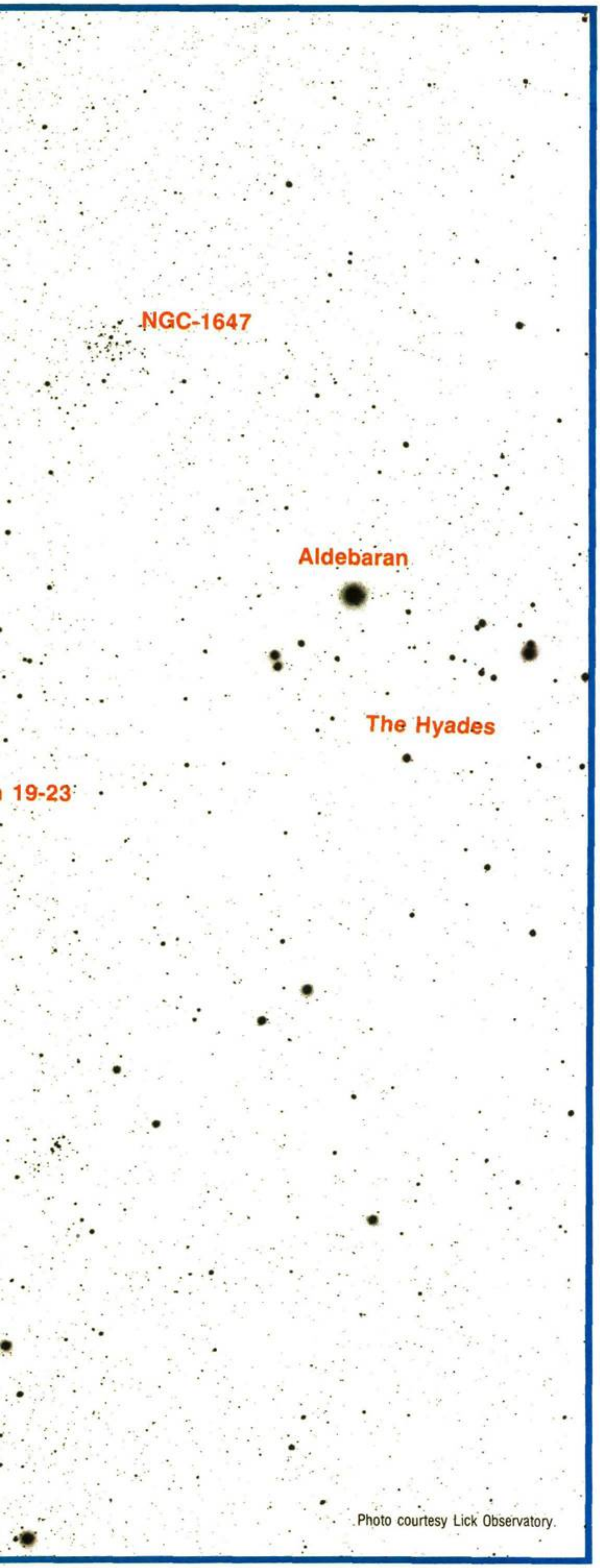


Photo courtesy Lick Observatory.

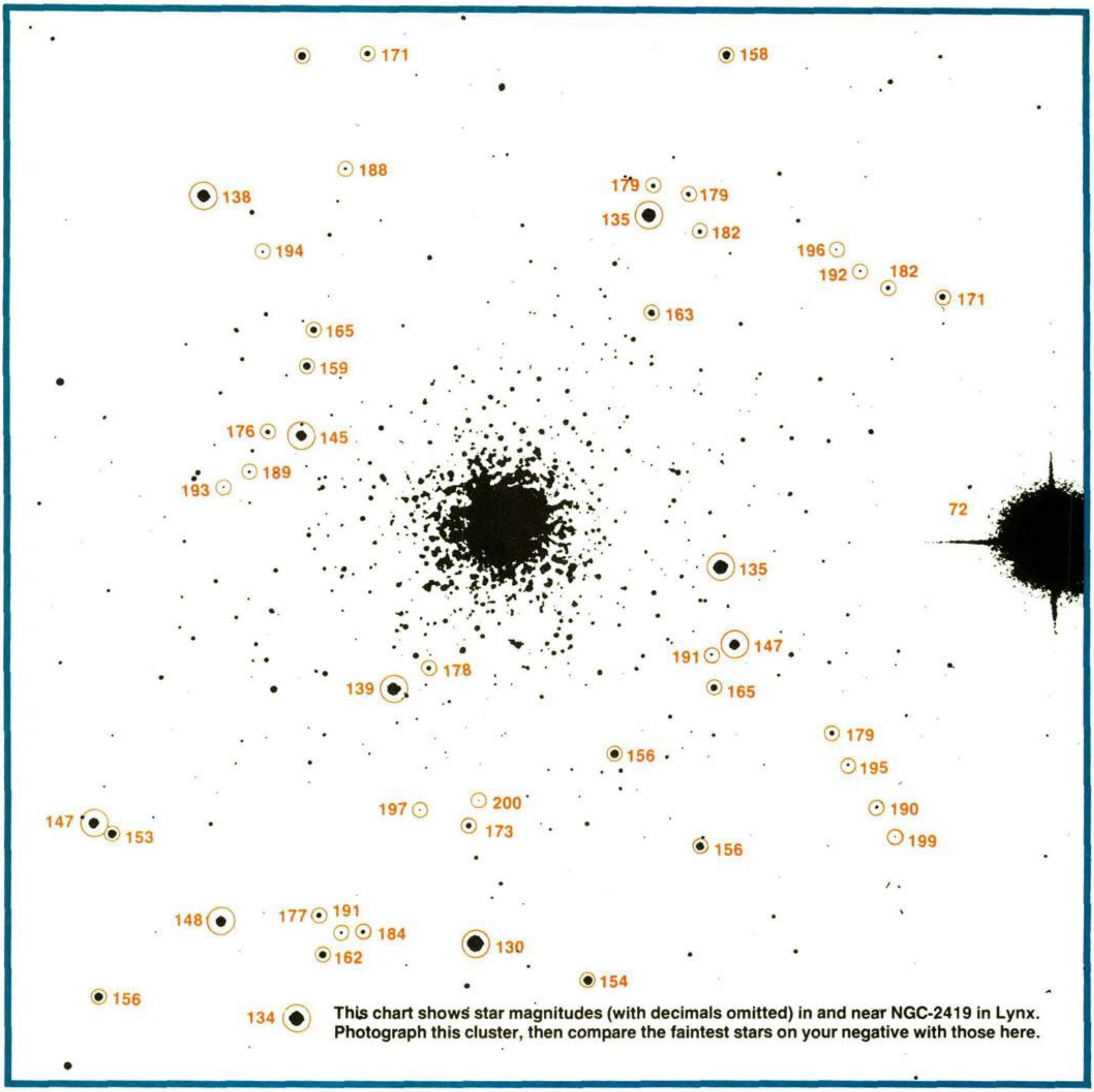
Blinking for Halley

To re-discover Comet Halley you'll need a pair of negatives or color slides. How? Let's say you shoot the region centered on right ascension 6 hours 3 minutes, declination +19 degrees 7 minutes any time between tonight and August 16. We now have a control record of the precise area where Comet Halley will be on the New Moon night of the third Thursday in August. If your magnitude tests show you can record images to 15th magnitude, then a photograph taken around August 16th will contain not only the myriad stars of the Milky Way in Orion, but also a glimmer of our elusive solar system wanderer.

You know almost exactly where to look in our August photograph for Halley, but to establish its identity beyond a shadow of a doubt, you must check this picture against your earlier reference slide. If you compare the reference photo with the data record, by "blinking" the data slide against the reference, the image of Halley will flash on and off — and thus will be relatively easy to find. It may be the 10,001st object in the data slide where the reference slide only showed 10,000. To blink the slides, construct a simple device called PROBLICOM — a PROjection BLInk COMparator.

Halley's Positions

February 1985	**R.A. (2000) Dec.**
17	5h04.7m, +13°13′
18	5h04.3m, +13°15′
19 (New Moon)	5h03.7m, +13°18′
20	5h03.1m, +13°20′
21	5h02.6m, +13°22′
March 1985	
19	4h54.4m, +14°24′
20	4h54.3m, +14°26′
21 (NM)	4h54.2m, +14°29′
22	4h54.1m, +14°31′
23	4h54.1m, +14°34′
April 1985	
18	4h57.0m, +15°41′
19	4h57.3m, +15°43′
20 (NM)	4h57.5m, +15°46′
21	4h57.9m, +15°49′
22	4h58.1m, +15°51′
May 1985	
17	5h08.4m, +16°51′
18	5h08.8m, +16°53′
19 (NM)	5h09.3m, +16°56′
20	5h09.7m, +16°58′
21	5h10.4m, +17°00′
June 1985	
16	5h25.3m, +17°52′
17	5h26.0m, +17°53′
18 (NM)	5h26.6m, +17°55′
19	5h27.2m, +17°57′
20	5h27.9m, +17°58′



This chart shows star magnitudes (with decimals omitted) in and near NGC-2419 in Lynx. Photograph this cluster, then compare the faintest stars on your negative with those here.

Photo courtesy U.S. Naval Observatory.

Photo courtesy U.S. Naval Observatory

NGC-2419, photographed with the U.S. Naval Observatory's 61-inch astrometric reflector at Flagstaff, Arizona.

Photo by Martin Germano

NGC-2419, photographed using an 8-inch f/10 SCT, 103a-F film, and a 45-minute exposure.

By alternately projecting the two slides through a pair of slide-projectors — using an occulting shutter, which presents the reference slide and then the data slide in rapid succession — the comet will appear to blink on and off. Such a device is fairly easy to make, requiring only a 120 r.p.m. motor and a simple rack to steady the projectors. (See "Blink For a Nova," ASTRONOMY, May 1978 and *Starwatch*, a book published by Putnam in 1984.)

The International Halley Watch, in cooperation with the Problicom Program and Celestron Telescopes, is offering a cash prize for the first successful Halley photograph.

Ben Mayer, a well-known amateur astronomer, lives in Los Angeles. He created the Problicom Program in 1977, and his book Starwatch *was published last year.*

ASTRONOMY
Reviews

How to Make a Telescope, 2nd ed.
Jean Texereau
242 pages, hardcover, $19.95
Willmann-Bell (1984)

When I was in ninth grade, my interest in astronomy was brand new and the stars were literally in my eyes. Browsing through a library one day, my hands fell on a remarkable book. It was the thin first edition of Jean Texereau's *How to Make a Telescope*. I had encountered the *Amateur Telescope Making* books edited by Albert Ingalls somewhat earlier and had come to the conclusion that building my own telescope was an impossibly difficult task. But here was Texereau describing in simple terms how to complete an instrument from start to finish and doing so without "talking down" to the reader.

The book gave me a bad case of TM fever, but my sanity did not totally depart; I saved my money for college instead of spending it on what I really wanted. I remembered Texereau, though, and when the opportunity to make a telescope did arise, I knew what book to read.

My first mirror was an 8-inch f/6, and it turned out perfectly. It is still my mirror of choice when I require high resolution, and I'm just as satisfied with it now as when it was new. Texereau was responsible for a minor miracle — many mirrors and thousands of hours of observing later, I still regard that first mirror as my best. Texereau had taken a rank beginner, working with only the printed page to guide him, and told him how to make a diffraction-limited mirror.

You can imagine my growing concern as this book became increasingly hard to find. Commercial distributors were dropping the title as copies ran out, and the book began disappearing from libraries — always a bad sign. I was desperate because I did not yet *own* a copy. I once offered someone $10 for a scruffy paperback copy, but he refused the money!

Finally in 1984, Willmann-Bell announced the second edition of this TM classic. I had long ago heard of a 1961 French edition (it was almost a legend among English-speaking TMs), but although I had taken a couple years of French, I didn't think I was up to reading a book-length technical work in it. Luckily, it has now been done for me, translated from French into English by Allen Strickler.

What is the result? The translation flows effortlessly. We are not treated to any "then you take the rubby-thing and put it down on the glass" type of mistakes that are so abundant when someone unfamiliar with the jargon translates a technical work. Strickler's experience in telescope making is helpful to both translation and the reader.

But translation aside, the book has that same feeling of total mastery as the original. Have you ever had the feeling when reading a popular astronomy book with a title like *Black Holes: Funnels of Doom*, that the author knew about as much as you did — and that the only difference between you and him was an afternoon at the library? Well, this book has the opposite effect: you feel that even if you started right now and devoted your entire life to mirror making, you would never know as much as Texereau.

The new edition is much thicker than the first and has become a manual for advanced workers, as well as a beginner's tutorial. (One minor complaint: I wish the sections of interest to beginners were more clearly marked. The beginner must hop over a lot of advanced material between the elementary sections.) It has sections on Cassegrain telescopes and a detailed treatment of making optical windows to seal the tube. Here we see Texereau's sound judgment. It's obvious he has spent a lot of time making optical windows. But even though they are a pet project, he says they are a waste of time for telescopes smaller than 8 inches' aperture, unless the telescope is otherwise perfect and the observer skillful. The book also has new material on equatorial mountings, and some excellent advice about turbulence and the realities of imaging.

The difference between Texereau's and other telescope-making books is the sophistication of his testing procedures. Other authors speak confidently of pitch and grits, and topics of interest in actually producing a mirror, but most fail to give the beginner a reliable method of testing and interpreting the test results. Not so with Texereau: he gives you the full story. Yet paradoxically, this is why some TMs are afraid of Texereau. I have heard people complain that his mathematical reduction procedure for mirrors is too complicated. Personally, I've never understood this attitude — after all, it's written out in cookbook form. I *will* admit that it is long and tedious, but then so is making a mirror!

For those with access to a small computer, publisher Perry Remaklus has included a computer program in generic BASIC that can do all these calculations automatically. Unfortunately, there are some errors in it, but I'm sure that Mr. Remaklus will soon supply an insert correcting these errors. *[He has — ed.]*

Something should be said about the publisher-added appendices, since they comprise a fourth of the book and are the only area that gave me cause for criticism. By and large, they are very good. In addition to the computer programs, there are references to the Dobsonian design (lacking, of course, in the 1961 text) and indexes to the main amateur telescope-making literature. The one addition for which I can find no use is Appendix K — Unusual Amateur Telescopes. This appendix is guaranteed to lure some poor unsuspecting beginner into projects that are sure to fail. Even if this chapter had a big "Beginner's Beware" sign on it, are the four pages on Norman James' proto-Astroscan necessary? I don't think so.

This one flaw mars an otherwise perfect book. I'm convinced that as manufacturers continue to raise the price of finished optics, more and more folks are going to

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be driven to make their own mirrors once again, dragging mirror-making out of its present 10 to 15-year doldrums — the result of cheap optics. With this book, you have every chance of building what Texereau calls "a telescope that is optically beyond reproach." *Dick Suiter.*

Accretion-Driven Stellar X-Ray Sources

Walter H.G. Lewin and
Edward P.J. Van de Heuvel, eds.
450 pages, hardcover, $79.50
Cambridge University Press (1984)

This multi-author volume reviews our current understanding of X-ray sources fueled by the accretion of matter. Among the topics discussed: X-ray pulsars in massive binary systems, X-ray "bursters," high-energy electromagnetic radiation from normal galaxies, SS-433, mass transfer and accretion disks, and the evolution of X-ray binaries. According to the publisher, the book's editors made considerable effort to provide a systematic description of accretion in binary star systems.

Precision Polar Axis Finder

Roger Tuthill, Inc.
$125

The Tuthill Precision Polar Axis Finder is designed primarily for people who own a fork-mounted SCT on a portable equatorial. It will enable you to position your scope quickly without leveling the tripod or knowing the exact geographic location of the observing site. As I'll describe later, it is also somewhat adaptable to other types of mountings.

The polar axis finder consists of four major components: a modified 4x gunsight, an aluminum mounting plate, a chart giving the orientation of Polaris to the celestial pole for every hour of every day of the year, and a dial/pointer to show the position of the North Star at any hour.

The gunsight's optical axis is permanently offset by the distance of Polaris from the celestial pole. The finder mounts easily with the bracket supplied so its barrel points in the same direction as the polar axis of your scope. With a fork-mounted SCT, you can easily collimate the finder to your scope's polar axis. When the mount is adjusted so that the gunsight points to Polaris, your main scope is centered directly and precisely on the north celestial pole. The polar alignment technique is simple once you have the actual instrument in your hands and can spend a few minutes familiarizing yourself with its operation.

I ran a test with my 4-inch SCT last October. After aligning the scope on the pole, I connected the clock drive, plugged in the drive corrector, and turned the scope on Jupiter. Tracking for half an hour was no problem. The planet remained centered in the crosshairs of the main scope the entire time. Nearby Mars also tracked well. Since Lambda Sagittarii in the Teapot was just south of Mars, I readjusted the drive corrector and centered the star in the field of view. It remained exactly centered during my hour-long test.

I left the scope undisturbed overnight. The following day was perfect for solar observations, so I put in my Hα viewer to observe prominences and flares. The viewer has a flat black circular disk in front of it, which is positioned to block out the Sun's disk and allows viewing of the prominences around its circumference. Viewing this way requires *extremely* accurate tracking. Since my mounting was still aligned, I merely set the drive corrector to the solar rate. The scope kept the prominences perfectly positioned around the disk for over two hours.

As for faults, I wish the instruction sheet was more clearly worded — especially the directions for ultrafine polar corrections. Does the polar finder work with a German-style equatorial mount? Yes, but you will have to drill a few holes in the aluminum plate (supplied) to adapt it to your polar axis. If you are planning to build a portable German equatorial mount, the finder could also be incorporated.

Tuthill has made one change in his finder since my model. Instead of illuminating the gunsight's crosshairs with fiber optics, he has painted them with phosphorescent material. If you shine a flashlight into the eyepiece of the gunsight for a few minutes, they'll glow for half an hour or so.

Properly used, this is a worthwhile accessory. *Don Trombino.*

Exploring the Night Sky with Binoculars

David Chandler
45 pages, softcover, $5.95
David Chandler (1983)
(publisher's address: P.O. Box 309, La Verne, CA 91750)

From the creator of what I consider to be the best planisphere available (*The Night Sky*), comes *Exploring the Night Sky with Binoculars*, a companion to that star dial. Taken together, the two items — plus a pair of binoculars — constitute the best introduction to observational astronomy you could ask for.

The booklet is logically arranged and engagingly written. Chandler gently takes your hand and leads you on an exploration of the universe, starting directly with the pleasures of viewing the night sky. Readers who follow the suggestions of this book can avoid the pitfalls that discourage so many amateur astronomers just starting out.

No better way exists to begin observing the Moon, planets, and stars than through binoculars. Chandler explains why and —

more importantly — how. Clear drawings enable you to find the binocular objects, while the text describes what you'll see and explains its significance. The booklet also includes some excellent black and white, air-brush paintings by space artist Don Davis. Indeed, his paintings of the Moon and other objects as seen through binoculars are not only pleasing, but extremely useful.

Throughout the booklet, the information is clear, accurate, and comprehensive. The reader is not overwhelmed by too much, or left frustrated with too little. Once you become familiar with the sights described in this book, then — and only then — should you consider purchasing a telescope. And Chandler even provides some intelligent advice about that. *John Mood.*

25 Graphics Programs in Microsoft BASIC

Timothy J. O'Malley
150 pages, hardcover, $17.95
Tab Books (1983)

Users of Microsoft will appreciate this book, which is full of graphics programs of all types. It details how to get up and running with two- and three-dimensional graphing, high-resolution graphics and line elimination, animated graphics, and computer art.

Atoms of Silence

Hubert Reeves
244 pages, hardcover, $14.95
MIT Press (1984)

Translated from the French and subtitled "An Exploration of Cosmic Evolution," *Atoms of Silence* covers a wide range of related topics on astrophysics and cosmology. Reeves investigates the expansion of the universe, the ultimate fate of the universe, the dark night sky paradox, the gestation of matter, the elements and their varying complexity, and the relationship between space and time.

Almanac for Computers 1985

LeRoy E. Doggett and Susana E. Deustua
100 pages approx., paperback, $4.25
U.S. Government Printing Office (1984)

Prepared at the U.S. Naval Observatory, the annual *Almanac for Computers* provides algorithms and coefficients for calculating some of the astronomical data that appear in the *Astronomical Almanac* — chiefly the positions of the Sun, Moon, and planets. (Some observers prefer to compute the data they need directly rather than interpolating from tables in the *A.A.*) Order from the Government Printing Office, Washington, DC, using stock number 008-054-00115-7.

The Early Years of Radio Astronomy

Woodruff T. Sullivan, ed.
421 pages, hardcover, $39.50
Cambridge University Press (1984)

In 1982, Sullivan edited a volume of classic papers on radio astronomy; in this work, he has collected personal reminiscences and memoirs from many of the chief participants involved in the beginnings of radio astronomy. The largest sections deal with developments in Australia and England, but also touched on are early Soviet, French, Canadian, Japanese, and American research as well. Though aimed at a professional audience, much of the book will be comprehensible to any lay reader interested in the subject.

The Astronomical Almanac 1985

U.S. Naval Observatory and Royal Greenwich Observatory
500 pages approx., hardcover, $17
U.S. Government Printing Office (1984)

The 1985 volume of the *Astronomical Almanac* contains daily positions for the Sun, Moon, and all the planets (except Pluto: every five days). It also tabulates physical data on the planets such as apparent size, magnitude, distance from Earth, and their equators and poles. Sections tell where to look for the moons of Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. It also gives positions of the first four asteroids, and contains a 1500-entry star catalogue. Order the *Astronomical Almanac* as stock number 008-054-00097-5 from the Government Printing Office in Washington, DC.

The Birth of History and Philosophy of Science

Nicholas Jardine
301 pages, hardcover, $59.50
Cambridge University Press (1984)

After providing a translation of a polemical book by Johannes Kepler (*A Defense of Tycho Against Ursus*), Jardine also explores the controversy behind the work. (Kepler's opponent, Nicholaus Ursus, claimed that astronomers were not competent to form hypotheses about the universe.) Jardine shows what Kepler's defense can tell us about early 17th century astronomy.

Stars and Planets

Robin Kerrod
125 pages, softcover, $6.95
Arco Publishing (1984)

Stars and Planets is a pocket-sized general introduction to astronomy which includes a simple star atlas and Moon map, and definitions for planets, asteroids, stars, nebulae, galaxies, and other celestial objects.

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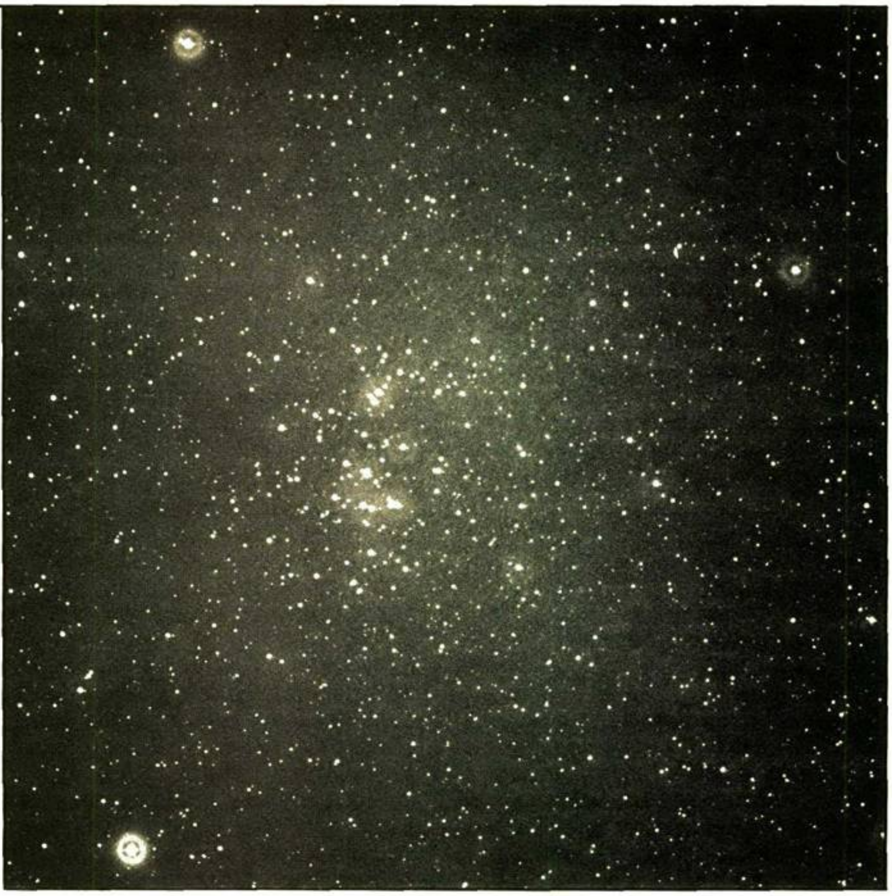
Venus at its Best

by Fred Schaaf



Right: Shortly after sunset on October 26th, Gordon Macdonald took this photo showing the Moon and Venus together. He shot Ektachrome 200 film at f/5.6 with a 300 mm lens and a 4-second exposure. Above: A binocular view (north at top) of M-44, the Beehive Cluster in Cancer. The two stars on the left are γ and δ Cancri, at top right is η. Photo by Rick Dilsizian.

The Wanderers

After spending weeks within 10° of each other in the evening sky, **Venus** finally "catches" and passes Mars on February 8th, only to fall back westward of it for a second conjunction in right ascension on February 15th. During this time, Venus is around its highest elevation for this evening apparition and is within two weeks of greatest brilliancy.

In the eight-year cycle of Venus' appearances, this month's peak altitude is one of the best for observers at mid-northern latitudes. Although Venus was at greatest elongation last month, in early February both its northward movement and the angle of the ecliptic to the horizon place it even higher in the sky. At sunset, when Venus is easily bright enough to detect with the naked eye, it will be more than 40° above the southwest horizon. (In fact, now is a good time to try finding Venus in the mid-day sky with binoculars.) On February 26th when it reaches greatest brilliancy, Venus will shine, dazzling white, at magnitude −4.6.

Never more than 5° from Venus all month is **Mars**, a yellowy-orange planet almost six magnitudes fainter than Venus. These two planets keep a fair distance from each other — even at conjunction — because Venus is north of the ecliptic (almost 8° north by inferior conjunction in early April) and Mars still lies a bit south of the ecliptic. At the February 8th conjunction, Venus passes 2.7° north of Mars; on the 15th the gap will be 3.8°. Only binoculars, very wide-field telescopes, or the naked eye will show the two objects together.

Remember that while Venus and Mars move little with respect to each other and the Sun during February, they are racing northeastward relative to the starry background. To detect this motion, notice where Mars and Venus appear against the stellar landmarks in the western sky each night.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

The apparent motions of Venus and Mars on the celestial sphere are nearly matched, but their orbital situations are profoundly different. Venus is on the near side of its orbit and about to pass in front of the Sun (inferior conjunction is in April). Mars is on the far side of its orbit and will soon fall behind the Sun (superior conjunction is in July). You can get a "top view" of the situation by looking at the diagram on page 82 in The Backyard Astronomer.

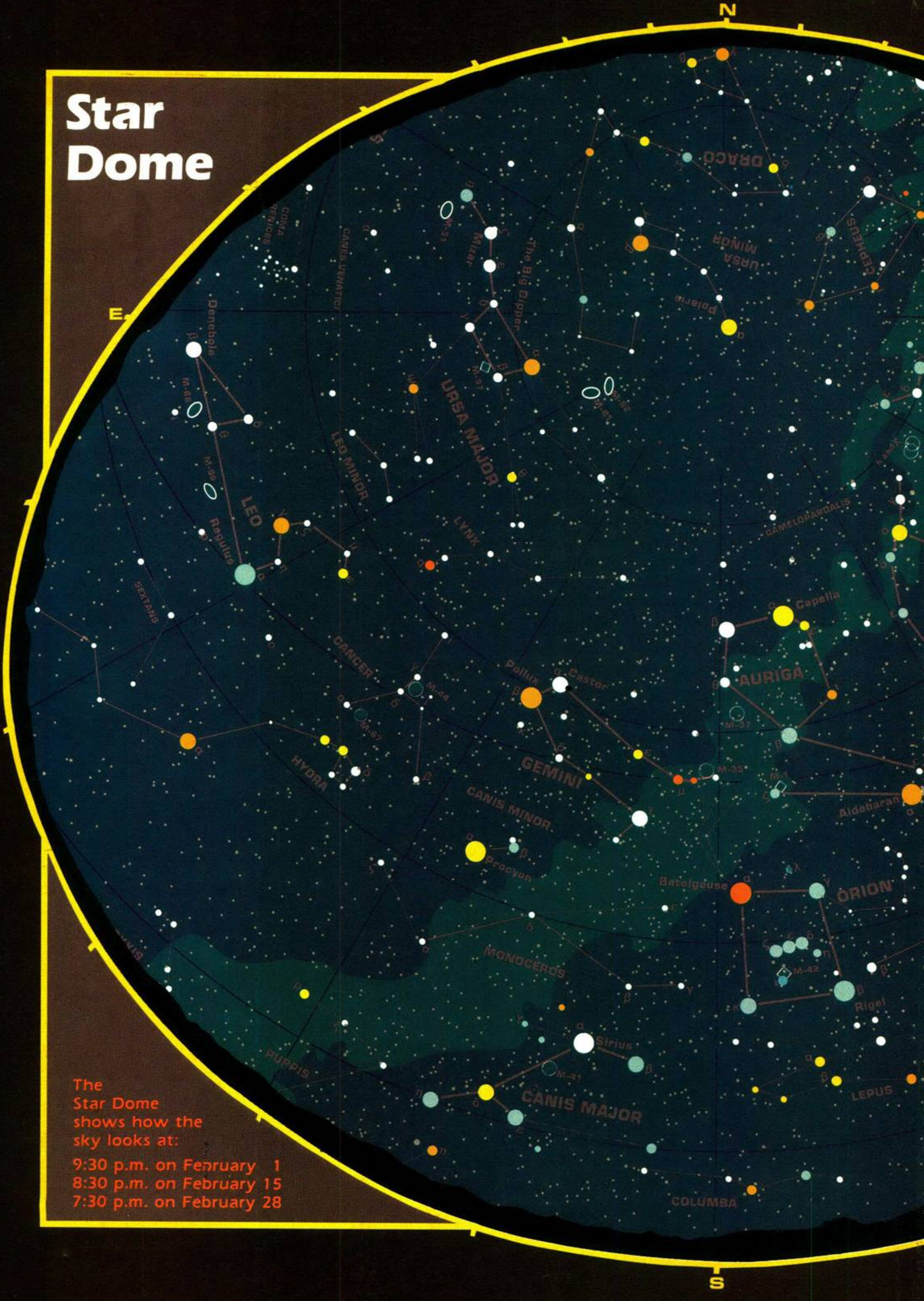
How unusual is it to have two conjunctions of Venus and Mars within a week? Some observers may recall pairs of these conjunctions occurring a month or two apart in recent years. No other equally-rapid pairings of Venus-Mars conjunctions are scheduled until 2029, when two of them will occur 13 days apart. After that event — which some of us will live to see — the two planets won't produce close pairings of Venus-Mars conjunctions for a long time: the next close pair of conjunctions comes in 2230!

You can compare the colors of Venus and Mars, using the former to find the latter, soon after sunset. **Mercury** enters the evening sky on the 19th — the same day as New Moon — but will be invisible nearly all month. During March, however, Mercury will reach the peak of an excellent evening apparition.

All the planets farther from the Sun than Mars are in the morning sky. The first naked-eye planet to rise is white **Saturn**, which is nearing the meridian by morning twilight. It lies in eastern Libra and is a little brighter than Antares, the orangy star in Scorpius, to the east of it. Morning is also the time to look for gleaming white **Jupiter**. This −1.9 magnitude planet emerges from the morning twilight by late February and can be found in western Capricornus, low in the southeast before sunrise.

February is one of two times in the year when you can search for a phenomenon few observers ever see: the zodiacal light. Pick a time between Last Quarter and New Moon and go out to a location well away from town. After the Sun sets and evening twilight has faded, you should see a tall, faint cone of light extending upward from the western horizon along the ecliptic. This is produced by sunlight scattering off countless dust particles that orbit the Sun in the same plane as the

Star Dome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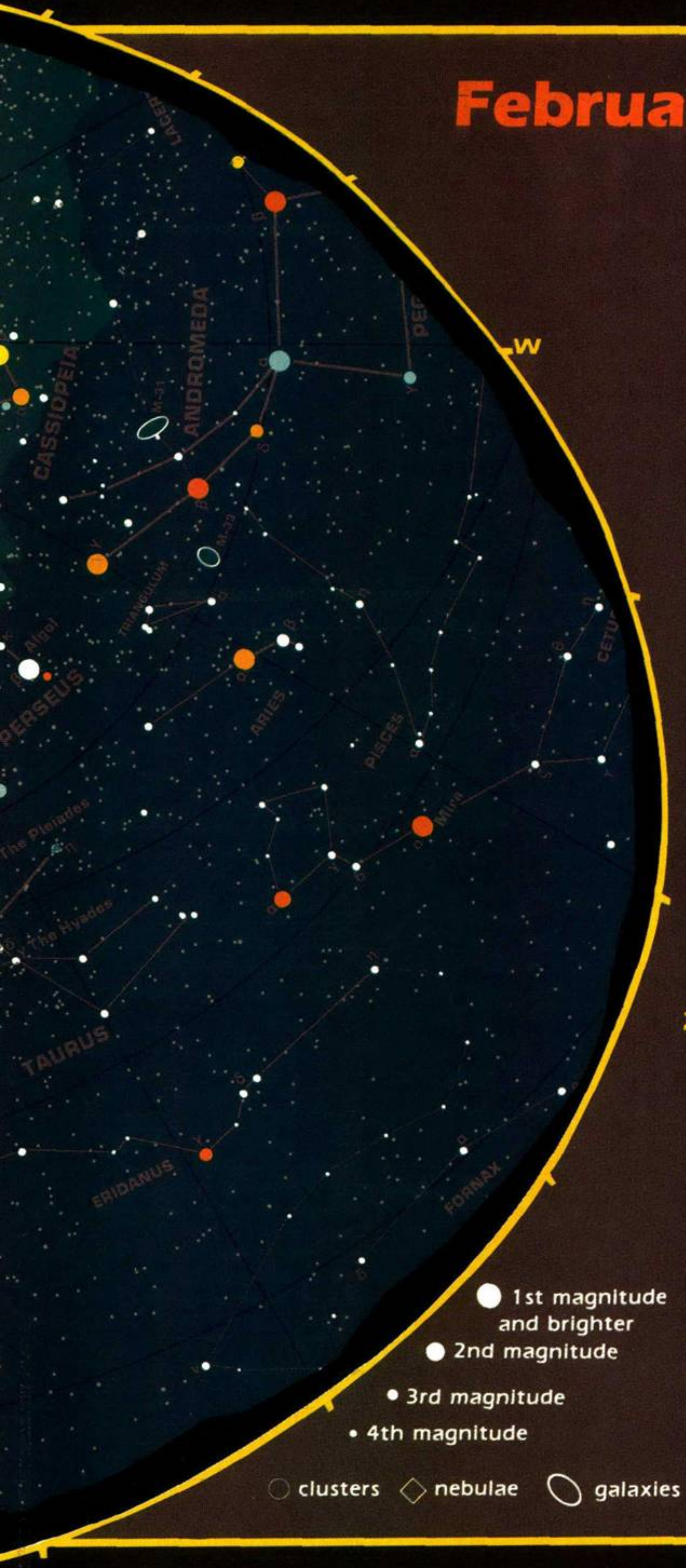
Capella
AURIGA
M-37
Castor
Pollux
CANCER
M-44
M-67
HYDRA
GEMINI
M-35
M-1
Aldebaran
CANIS MINOR
Procyon
Betelgeuse
ORION
M-42
Rigel
MONOCEROS
Sirius
M-41
CANIS MAJOR
PUPPIS
LEPUS
COLUMBA

The Star Dome shows how the sky looks at:

9:30 p.m. on February 1
8:30 p.m. on February 15
7:30 p.m. on February 28

February Sky Almanac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TRIANGULUM
Algol
PERSEUS
ARIES
PISCES
CETU
Mira
The Pleiades
The Hyades
TAURUS
ERIDANUS
FORNAX
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

5th Full Moon occurs at 10:19 a.m. EST.

7th The Moon is closest to Earth at 10:31 p.m. EST: 226,348 miles. Also look for Venus about 3° north of Mars in the evening sky.

12th Last Quarter Moon is at 2:57 a.m. EST. Later, it will pass 3° south of Saturn in the morning sky.

13th The next two weeks are a good time to look for the zodiacal light — a faint conical glow that rises in the west after evening twilight has faded.

15th Venus passes 4° north of Mars for the second of its two conjunctions this month.

17th The Moon lies 4° south of Jupiter in the morning sky.

19th New Moon occurs at 1:43 p.m. EST. Mercury passes through superior conjunction, switching from the morning sky to the evening, but you won't catch sight of it in the evening sky until early March.

22nd The Moon passes both Venus and Mars in the evening sky. This "double conjunction" won't be visible for everyone before the three objects set.

23rd The Moon is farthest from Earth at 10:57 p.m. EST: 251,972 miles.

26th Venus reaches greatest brilliancy (−4.6 magnitude) appearing as a blazing white object in the evening sky.

27th First Quarter Moon is at 6:41 p.m. EST.

planets. If you miss the zodiacal light now, you'll have to wait until mornings in October before you'll get the next good view.

The Starry Sky

As **Orion** the Hunter tilts westward, his Big Dog **Canis Major** leaps up toward the meridian. The dog's eye, head, or (as some say) his heart, is marked by Sirius. This magnitude -1.5 blue-white "Dog Star" outshines the other bright stars of this fine constellation by three to four magnitudes.

Beta (β) Canis Majoris rises just before Sirius and therefore is called Murzim, "the announcer." Brighter than Murzim, Aludra (η Canis Majoris), Wezen (δ), and Furud (ζ) is Adhara (ε). The southerly declination of these four stars greatly dims them for most middle latitude observers.

For anyone living north of about 30° north latitude, Sirius is the nearest star to the Sun that is prominent to the naked eye. It lies less than nine light-years away and about two and a half light-years closer to us than Procyon — the chief luminary of **Canis Minor**, the Little Dog. The space distance between the two is similar to that between our Sun and the Alpha Centauri system. These four star systems are the only dominant suns we find until we encounter Altair, somewhat less luminous than Sirius, at about 16 light-years out from Earth.

Altair (which is in the summer constellation Aquila) and Vega (in Lyra) are almost directly opposite Sirius and Procyon as seen from Earth. An observer on a planet orbiting Sirius would see our Sun as a respectably-bright star in the same region of the sky as Altair and Vega — both would be slightly dimmed in the sirian sky because of their increased distance. (The third member of the Summer Triangle, Deneb in Cygnus, is a superluminous star very far off and would be scarcely dimmed at all.)

Strangely, the form and brightness of Orion would barely change if we traveled to Sirius. Sirius is intrinsically 20 times more luminous than our Sun, but Rigel and its blue supergiant companions in Orion are about 2,000 to 3,000 times brighter still and roughly 150 times farther away. Sirius is a bright street lamp next door, while much farther away lie the immensely more powerful lights of the "city" of stars, Orion.

An observer in the sirian system would also see one star-like point of light, painfully intense in its brightness: the companion star of Sirius itself. If this star — Sirius B — were placed in the same orbit about *our* star, it would lie between the orbits of Uranus and Neptune much of the time. Sometimes called "the Pup," Sirius B is a telescopic star of low intrinsic luminosity and remarkably small size — it is a white dwarf star. Though smaller than the planets Uranus or Neptune, this star is so dense that it contains as much mass as the Sun.

A stretch of the Milky Way passes between Sirius and Procyon, but you need reasonably dark skies to see it well. With binoculars it's easy to pick out many of the beautiful star clusters in this region. The clusters scatter across dim **Monoceros** the Unicorn, and down across **Puppis** the Poop and **Vela** the Sails (both part of the old constellation-ship, Argo). Several conveniently placed and bright clusters in other constellations include M-41 (a few degrees south of Sirius) and M-35 (in the feet of Gemini) — both are detectable by the naked eye.

It has been said that poor Canis Minor looks more like a tail than a dog, but north of Procyon shine the comrade stars — Castor and Pollux. Castor is magnitude 1.6, Pollux 1.2, and the two stars lie about 4½° apart. They mark the heads of two mythological brothers represented by this constellation known as **Gemini** the Twins. (Can't remember which star and twin is which? Try this: Castor is the more northerly of the two — that is, the one nearest Polaris, the *caster* on which the sky rotates. And if you don't get this right, you'll be all "polluxed" up!)

The ecliptic (the path of the Sun and planets) passes between the Pleiades and

Left: To the east of Orion (right) lies a portion of the Milky Way including the constellation Monoceros and its round ruddy button, the Rosette Nebula. Photo by Tim Hunter who used 3M 1000 film, a 28mm lens, and a 10-minute exposure at f/2. He then recopied the photo onto Kodachrome 25, slightly adjusting the color balance with filters. Right: the Full Moon by Brian Tkachyk.

the Hyades — two beautiful open star clusters in **Taurus** the Bull — and then splits Gemini along a line from near M-35 to near **Wasat**. Wasat (whose name resembles that of a telecommunications satellite but is actually Arabic for "the middle") is Delta (δ) Geminorum. It was near this star that Clyde Tombaugh discovered Pluto, some 55 years ago. In addition, William Herschel discovered Uranus 204 years ago when it was close to Eta (η) Geminorum, sometimes called Propus, near M-35.

Skylore

Last month, we leapt from Lepus the Hare to the lore of lunar hares — those curiously worldwide and inexplicable legends connecting hares or rabbits to the Moon.

The hare and Moon are shown together on Euphratean cylinder seals, Syrian agate seals, and Chinese coins and Moon-cakes. Stories of hares and the Moon originated from cultures spanning several thousand years, including Japan, China, India, Africa, and North and South America. Could tales of a lunar hare spread so widely from one original source? Even if that were possible (and it seems unlikely), we must still wonder why the stories have proved compelling and enduring in so many cultures. *Is* there any obvious, natural connection between the Moon and hares?

One idea, mentioned by R. H. Allen in his book *Star Names*, is that both Moon and hares are largely nocturnal. Of course, many animals are nocturnal and the hare's most striking characteristics hardly suggest the Moon. What has the Moon to do with speed, timidity, or prolific reproduction? Allen mentions that a list of even more improbable explanations for the hare-Moon link occurs in Beaumont and Fletcher's play *The Faithful Shepherd*.

Could it be that the naked-eye markings on the Moon — the dark lunar maria and bright highlands — resemble the shape of a hare? Readers of Guy Ottewell's *Astronomical Calendar* may recall his sketches showing how the Man in the Moon, the Lady in the Moon, and a leaping Hare in the Moon can all be pictured in the maria — at least with a bit of imagination: Mare Crisium is the hare's tail and foreshortened Mare Frigoris his backswept ears. It is difficult, however, to believe this lunar hare is unmistakable enough to have sprung up independently in many different cultures.

Another objection is that legends exist relating the hare and Moon, but not depicting the animal on the Moon's face. For instance, a Bushman legend tells us of a hare who was the Moon's messenger to mankind. The animal falsified a crucial lunar communication that people could rise again after death, just as the Moon itself returns and waxes again after its "death" at New Moon. Since humanity didn't learn the truth, they lost the ability to return from death and became mortal. The angry Moon struck the hare across the mouth for this misdeed, giving the animal the split lip all hares have to this day.

Another story, from southern Africa, says the Moon acted badly to the hare and was punished for it: the hare jumped up and scratched her (the Moon's) face, producing the markings we see there.

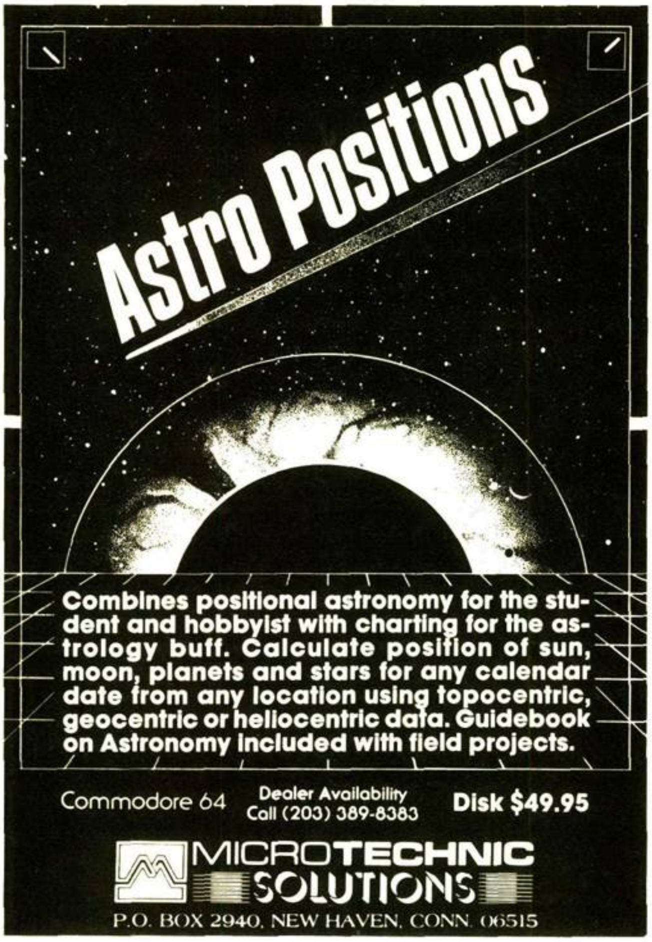
Patrick Moore retells a Chinese tale of a great drought during which elephants came to drink at a place called the Lake of the Moon. In their blundering haste to get to the water, they trampled many hares until one clever hare pointed out they were angering the Moon-goddess by disturbing her reflection in the water. The elephants were alarmed and departed.

Although such tales exist, most cultures picture the hare on the Moon itself. The Aztecs imagined a rabbit on the lunar face thrown up there by a god. A similar legend comes from India. A Hindu name for the Moon was Cacin or Sasanka, which means "marked with the hare." According to the story, Budda Sakyamuni was (in one of his earlier lives) a hare. One day while in the company of a fox and an ape, all three encountered a starving beggar who asked them for food. The ape went off and returned with some mangoes, the fox came back with a pot of milk, but the poor hare — unable to find anything — could offer only himself. The beggar thereupon built a fire into which the humble hare promptly jumped. Fortunately, the beggar was the god Indra in disguise. He rewarded Ṣakyamuni the hare by rescuing and placing him in the Moon as an honorable example for all to see.

According to Allen, Sanskrit and Sinhalese stories refer to a palace of the king of hares located on the Moon's face. Some of these tales may have spread from Chinese culture.

Allen also mentions the Japanese, who saw the Moon as a Jeweled Hare pounding *omochi* (a rice dough) in a mortar. This version is surely derived from an older Chinese account of a hare who makes the drug of immortality in the palace of the Moon.

A picture of this hare in the lunar palace is sometimes sacrificed to during the August Moon Festival (which now occurs in September or even later at the Harvest Moon). The sacrificial offering is one of fruit, a sprig of red amaranth, and Moon-cakes. Moon-cakes became famous at one point when Chinese rebels hid messages in them during their revolt against Mongol rule. At the Moon Festival, women and children — but not men — sometimes sacrifice fruit to little figures of white rabbits or helmeted soldiers with the face of a hare.



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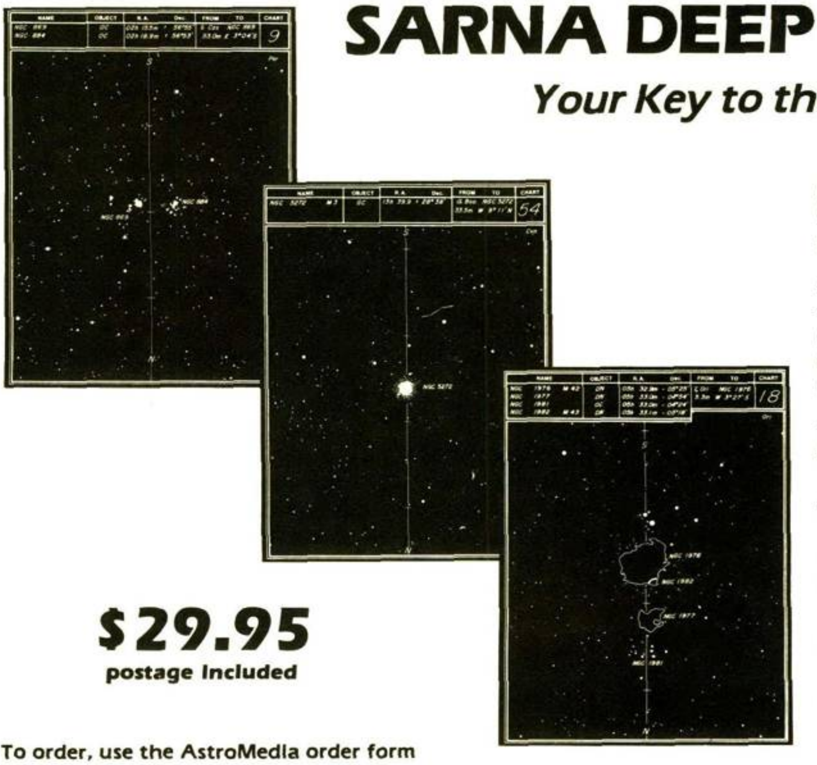

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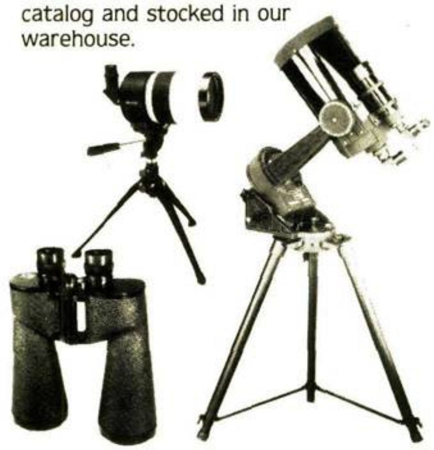

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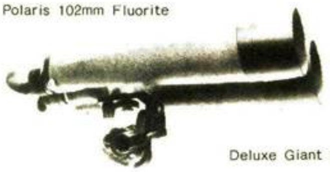

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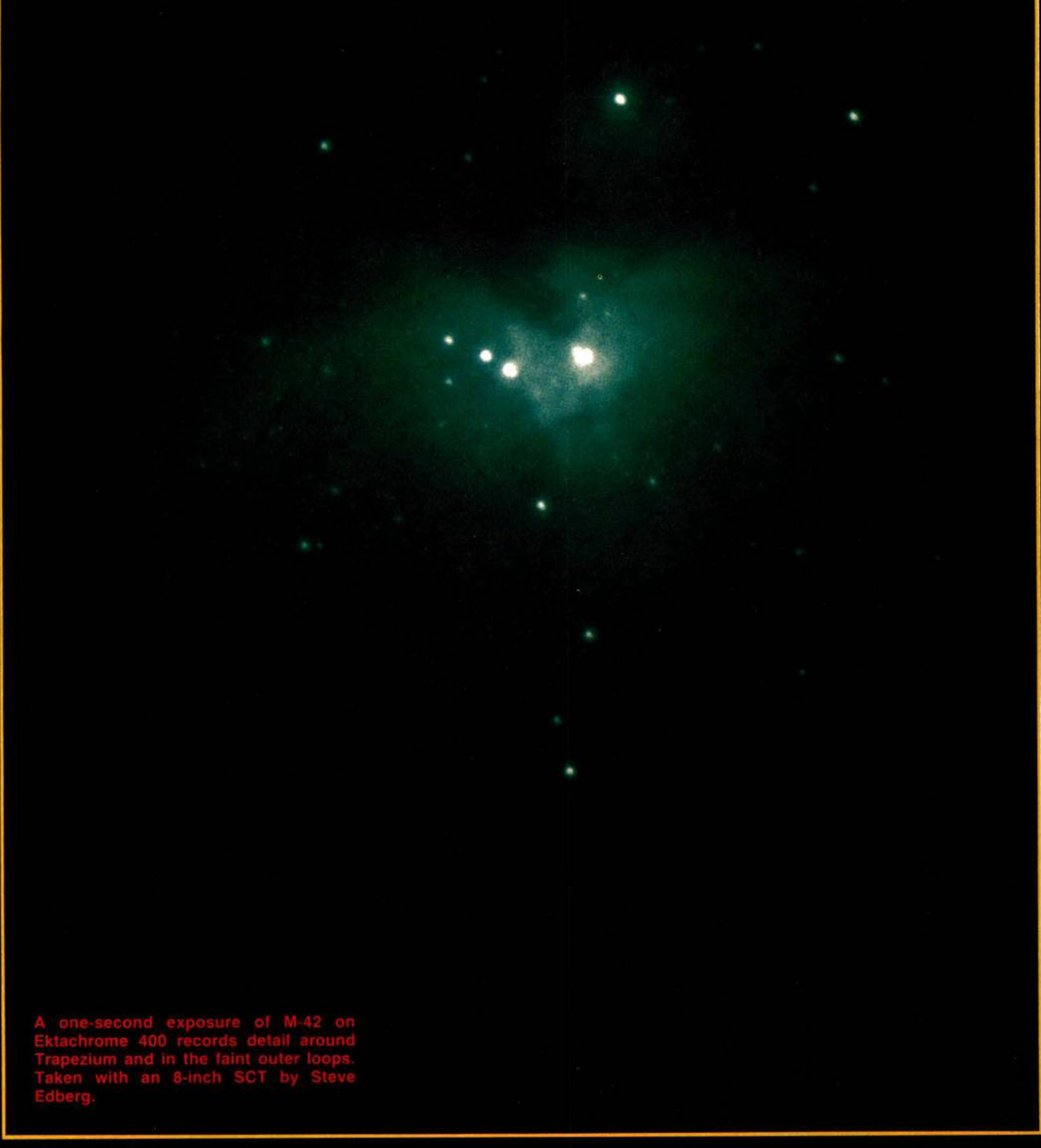
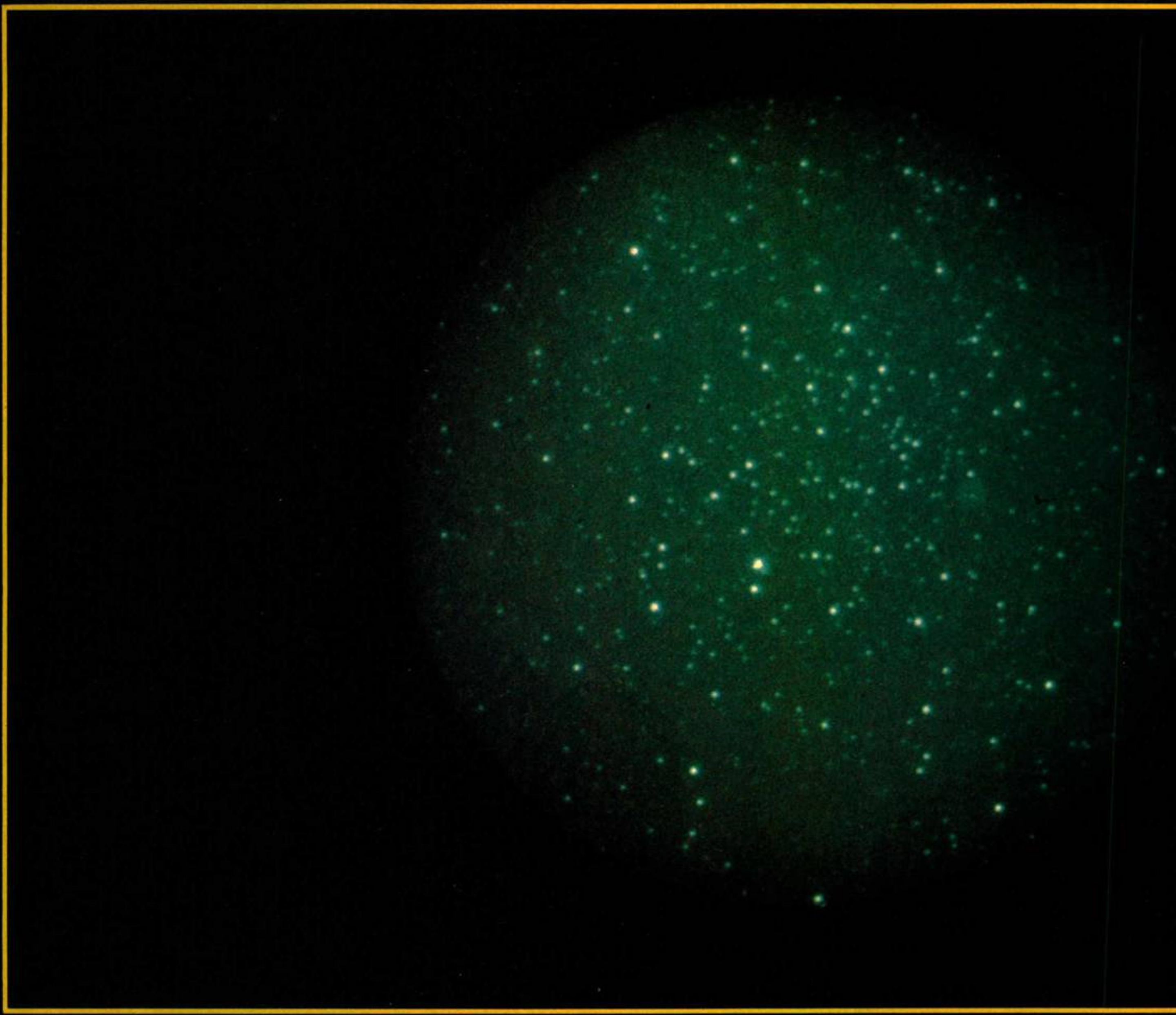
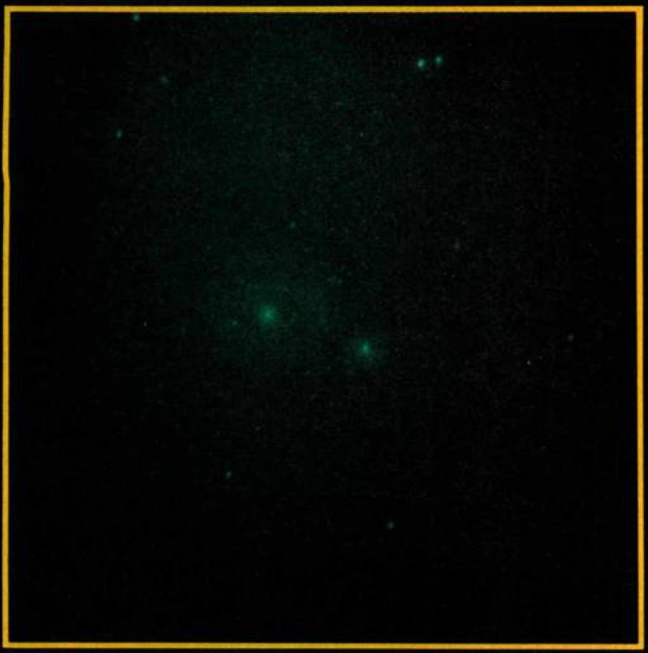
An Intensified Evening at the Telescope

by
Steve Edberg and Mark Coco



A one-second exposure of M-42 on Ektachrome 400 records detail around Trapezium and in the faint outer loops. Taken with an 8-inch SCT by Steve Edberg.





A 15-second exposure of open cluster M-46 in Puppis reveals planetary nebula NGC-2438 among the cluster stars. Taken with an 8-inch SCT on Ektachrome 400 film by Steve Edberg.

Far left: This eight-second exposure of M-51 shows how a typical galaxy appears with the intensifier when photographed on black & white film. Taken with an 8-inch SCT on Ektachrome 400 film by Steve Edberg.

Left: This 10-second exposure shows galaxy M-51 in Canes Venatici. The spiral arms are barely visible above the background sky brightness, which exhibits graininess due to scintillation and internal "dark noise" in the intensifier. Taken with an 8-inch SCT on Tri-X film by Mark Coco.

Perhaps you've heard about image intensifiers and wondered what they're like. We did, so when the chance to use a demonstration model presented itself, we jumped at the opportunity. Although we only had a few hours to test Litton's M-911 and M-841 miniature night vision scopes, we learned a lot in that short time. Our observing site, at an elevation of 5,000 feet on the Angeles Crest Highway in the San Gabriel Mountains, was well above the lights of the Los Angeles Basin.

We borrowed the intensifiers from a local Litton distributor. The two devices were almost identical. Both were equipped with the same second-generation microchannel plate. The main difference is the M-911 has a non-interchangeable eyepiece and objective, while the M-841 allows the observer to attach different eyepieces and objectives. This lets you attach the intensifier to a telescope and substitute a camera for the eyepiece.

We wanted to try photography with the intensifiers as well as direct viewing. Ever since we began doing deep-sky astrophotography, we've been looking for easier ways to photograph faint star clusters, nebulae, and galaxies. We have tried fast emulsions, hypered films, Schmidt cameras, and virtually every other technique that's come along, so we welcomed the chance to compare the performance of an intensifier to that of purely photographic techniques.

Image intensifiers, also known as "starlight scopes" and "night vision devices," work on a simple principle. An image intensifier takes light that has been focused on its photocathode and converts it into electronic impulses. The electronic impulses are then amplified — similar to the way a guitar amplifier increases the intensity of sound waves. Once amplified, the electronic impulse is converted back to light as the electrons strike a phosphor screen. The end result is a vivid green phosphor image that's thousands of times brighter than the actual scene. Although expensive, intensifiers are capable of multiplying the brightness of faint astronomical objects. Nebulae that take an hour to record on film take only a few seconds to photograph with an intensifier.

The M-911 unit we used came with a 26.8 mm f/1.1 objective lens. Although the eyepiece gave a 1x magnification (for a same-size view), the intensifier provided a brightness gain of 50,000 times. Looking at the ground through it, we could see even the darkest shadows. By simply handholding the intensifier like a binocular, we could scan around the sky and see stars down to eighth and ninth magnitudes. And more than stars could be seen — the Rosette Nebula in Monoceros was also easily visible.

One thing that struck us right away was scintillation — the image looks somewhat like a snowy TV picture. This is because the intensifier shows *photon noise,* the random fluctuation in the number of photons reaching the device. This effect is always present, but even at low light levels your eye usually ignores it. In the brightness-enhanced view through an intensifier, though, scintillation becomes evident.

Nonetheless, our first views through the image-intensifier-and-telescope combination were breathtaking. We chose the Orion Nebula, M-42, as our initial target. In an 8-inch SCT, the image was surprisingly bright. The faint outer loops of nebula stood out and were easily seen. We simply pointed the handheld intensifier into the eyepiece — just as you do for afocal photography with a camera. The intensifier increased M-42's apparent contrast, but curiously enough, it did not show more than could be seen looking directly through the telescope. The dust nebula around Merope in the Pleiades could *not* be seen, either with or without the intensifier.

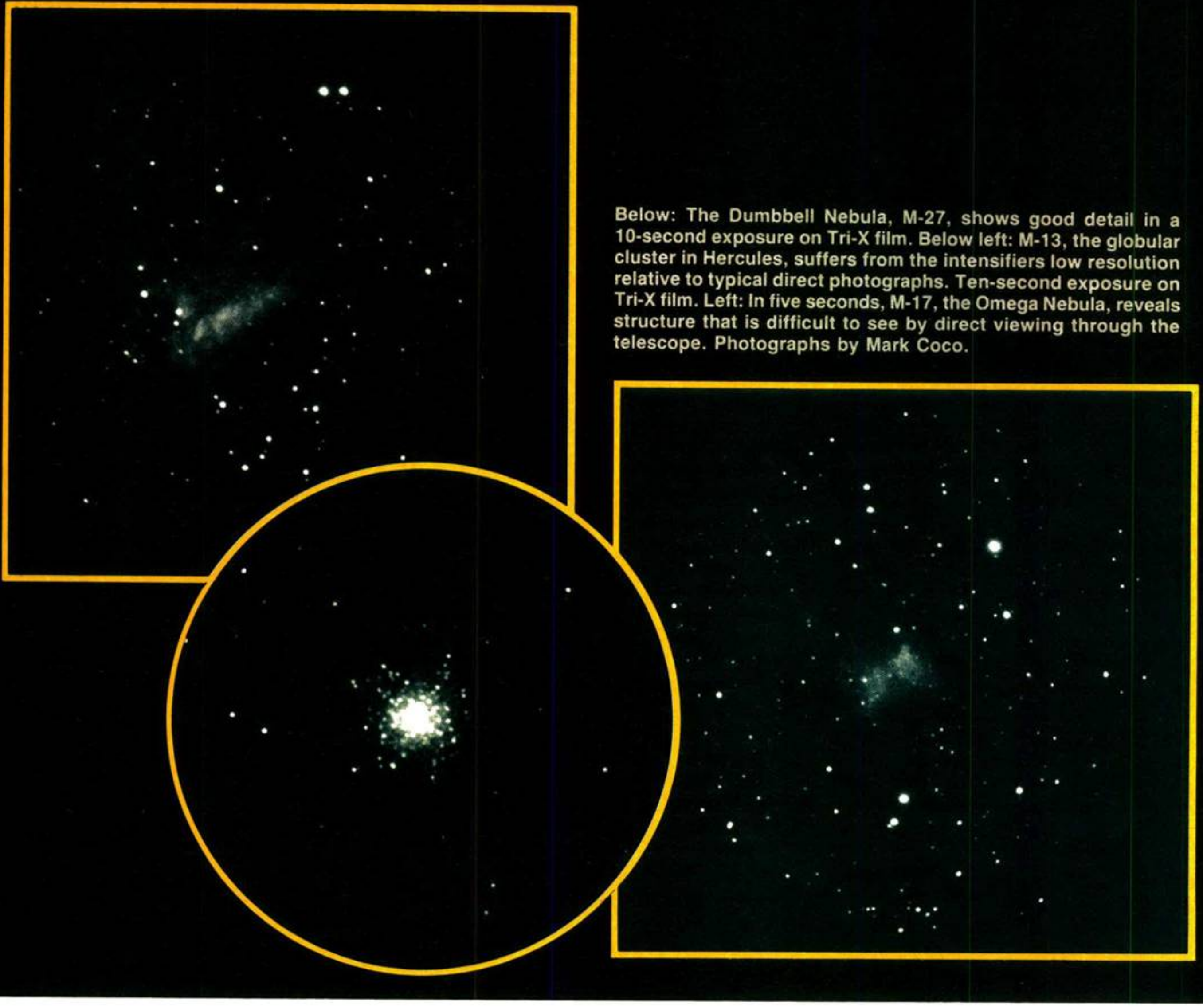
After putting the M-911 intensifier through its paces, we tested the M-841 for astrophotography. As the accompanying pictures show, we tried to look at every type of deep-sky object. The light gain of 50,000 times gives "instant" photography a new meaning! Exposures of no more than 10 seconds sufficed to capture almost everything we photographed. Intensifiers are so powerful that a photographic Messier Marathon — attempting to photograph as many Messier objects as possible in one night — is now feasible.

We found night viewers work best for black and white astrophotography. Because the final amplified image is green rather than the vibrant colors seen in long-exposure color astrophotographs, color film yields pictures that are green. This is distracting, so we recommend the black and white route. Some of the pictures in this article are green to give you a feel for what *looking* through an intensifier is like.

Our pictures also hint at the appearance of scintillation: little dots can be seen in the background. Each dot is the amplified image of a single photon, which appeared in the viewer as a little flash of light. Because still pictures cannot capture the effect, imagine seeing hundreds of tiny flashes across the field of view.

For photography, we used the camera's light meter to find the exposure: it indicated 10 seconds. We set the camera on its manual mode and made exposures of 5, 10, and 15 seconds. Even with an image intensifier, bracketing is a good idea. Throughout our observing session, we bracketed all shots to ensure properly exposed frames.

The processed slides were instructive. First, we found the intensifier produced a ¾" picture in the 35mm frame; it did not fill the frame. This is not objectionable since the picture can be cropped. Second, we discovered intensifier photos turn out fuzzier than direct photos. However, extended nebular objects are not as sensitive to the low resolution of the intensifier. Finally, we found very faint



Below: The Dumbbell Nebula, M-27, shows good detail in a 10-second exposure on Tri-X film. Below left: M-13, the globular cluster in Hercules, suffers from the intensifiers low resolution relative to typical direct photographs. Ten-second exposure on Tri-X film. Left: In five seconds, M-17, the Omega Nebula, reveals structure that is difficult to see by direct viewing through the telescope. Photographs by Mark Coco.

objects (like the Horsehead Nebula) do not record on film. Increasing the exposure time only brightens the background sky and washes out the target.

It is important to remember that observing circumstances play a big part in determining what an image intensifier can do for you. Contrast is the key to understanding why the intensifier usually doesn't help in observing faint nebulae or faint extensions from bright nebulae. The image intensifier is very democratic — it intensifies everything in the field of view equally. Sky background is intensified along with the target; if the sky is light polluted, the object won't be seen any better against the bright background when it's intensified.

Someone *observing from* an urban area will gain little from an intensifier; someone under dark skies will see great improvements in limiting magnitude. Light pollution filters can darken the sky background at both rural and city observing sites and should be a big help. Unfortunately, we didn't have time to try everything!

Direct color photography is not possible with an intensifier because of the green output of the screen. Tri-color photography could be done using appropriate red, green, and blue filters in front of the photocathode and black and white film to record the output (which would still look green, of course). Color could then be reconstructed in the darkroom. Short exposure times minimize problems involved in getting three good exposures of the same object. Likewise, a supernova search program would benefit because an observer could obtain lots of galaxy photographs per night. Blinking these against earlier images allows the observer to search many galaxies quickly, thus increasing his chances of discovering an elusive supernova.

What are the advantages and drawbacks on using an intensifier? On the plus side, they brighten the image and help you see faint stars. On the minus side, they ruin your night vision because the phosphor image is so bright. On the one hand, they brighten faint nebulae, but on the other, they reveal little a dark-adapted eye cannot see. And the intensified image is fuzzy, tiresomely green, and snowy.

But intensifiers do let you shoot deep-sky astrophotos quickly with minimum time and hassle. However, night vision devices that meet military specifications begin around $3,500 — enough to buy a 29-inch Dobsonian with change left over. At these prices it's not surprising so few amateurs own one.

All in all, image intensifiers are a lot of fun to use despite their drawbacks. All you have to do is attach it to the telescope, put on a camera body, and start photographing. Polar alignment doesn't have to be very accurate since you won't need exposures longer than 30 seconds. A drive corrector or guidescope is hardly necessary. Getting a good deep-sky photograph in seconds instead of hours is very satisfying. We look forward to the time when prices will be lower and average amateur astronomers will be able to afford intensifiers.

Steve Edberg is the coordinator of amateur observations for International Halley Watch and editor of the IHW *Amateur Observer's Bulletin. At the time of this writing, Mark Coco worked for a major telescope manufacturer. Both authors are active and experienced observers.*

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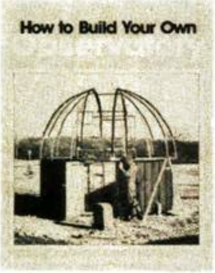

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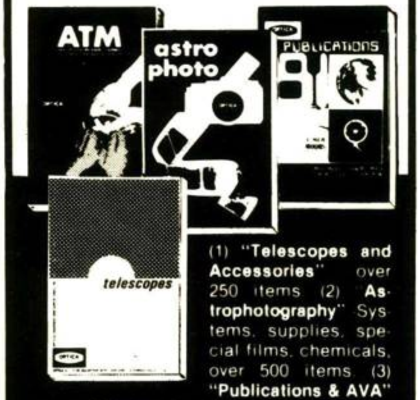

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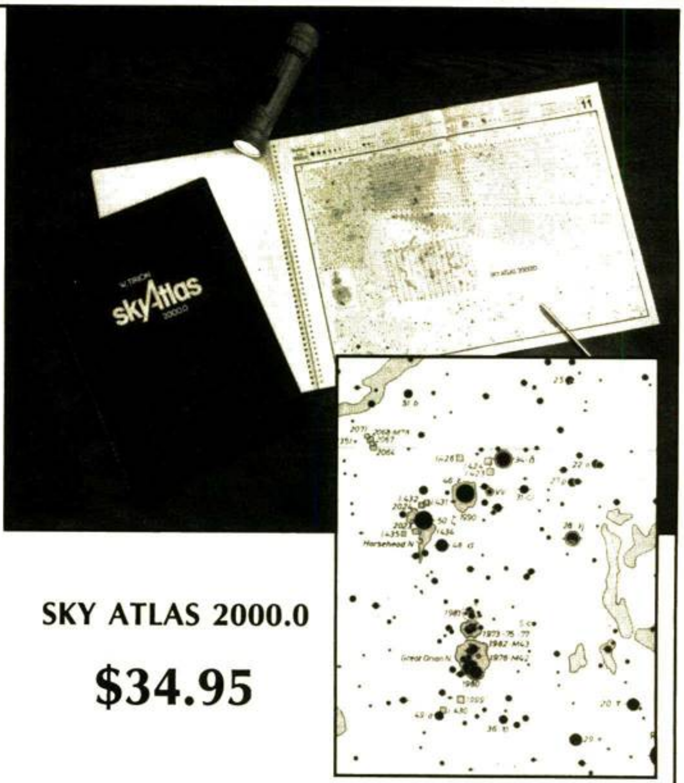

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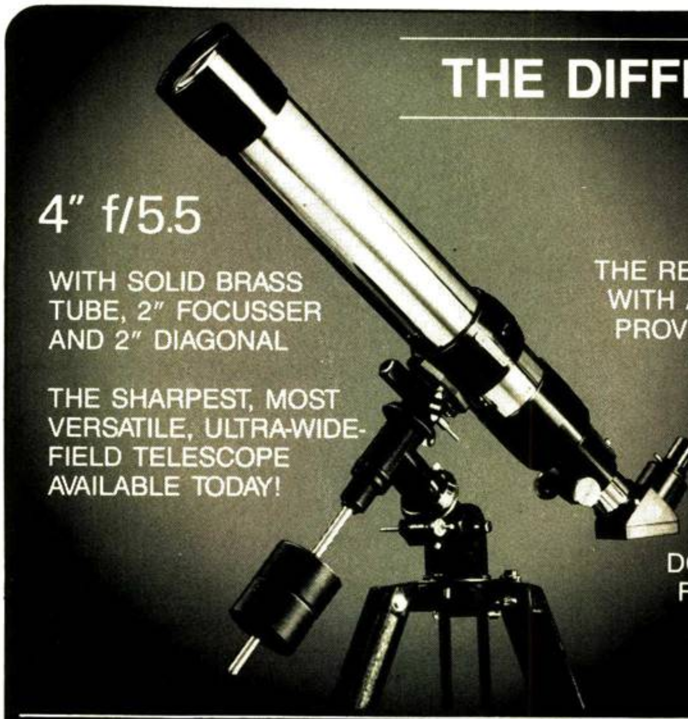

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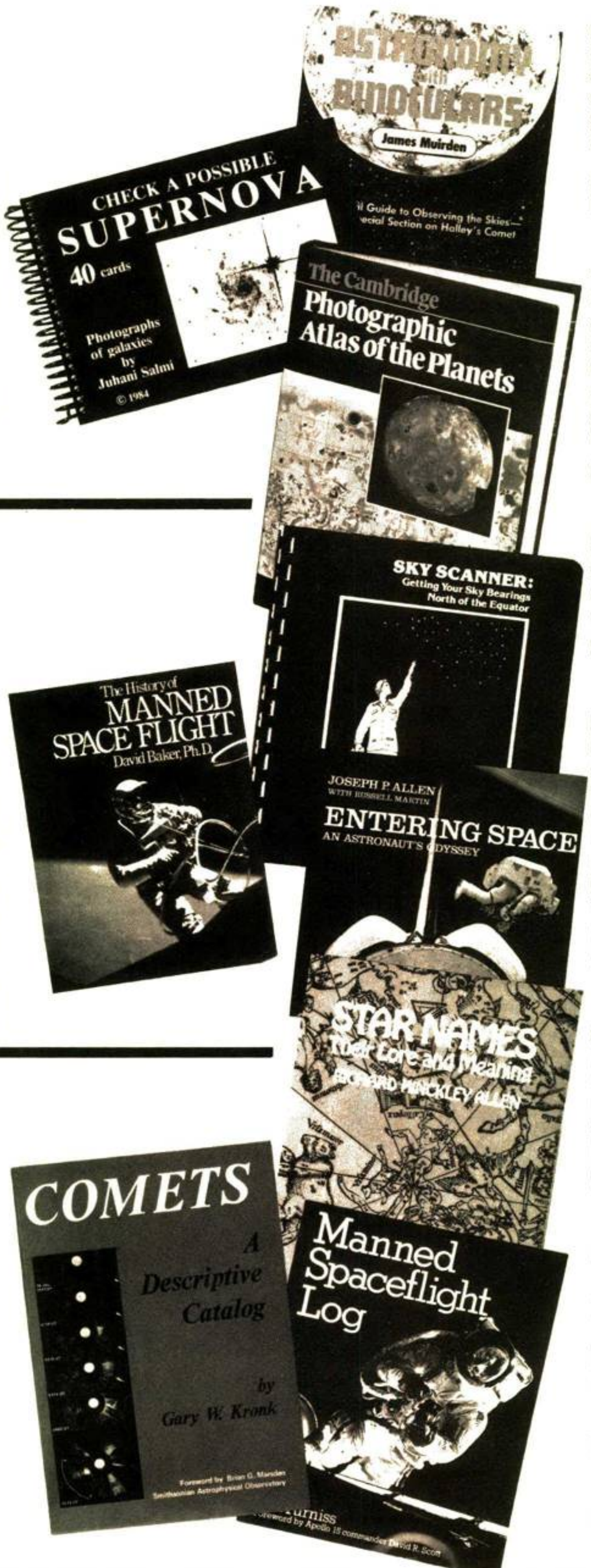
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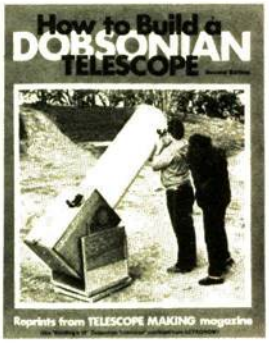

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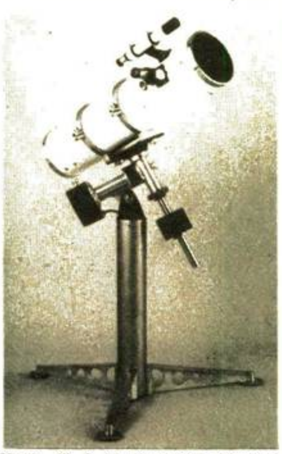

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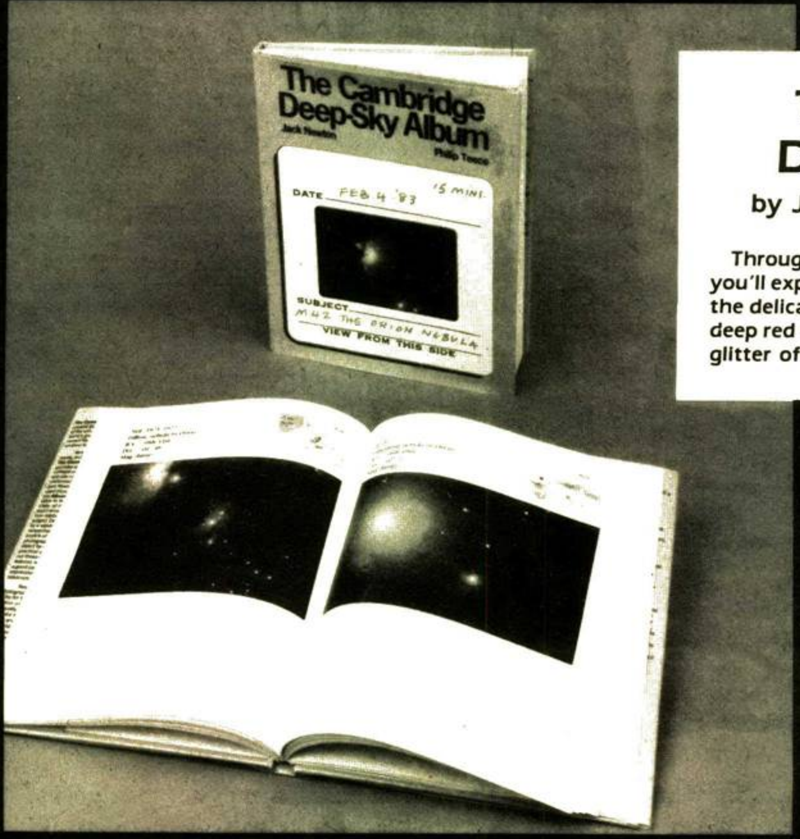

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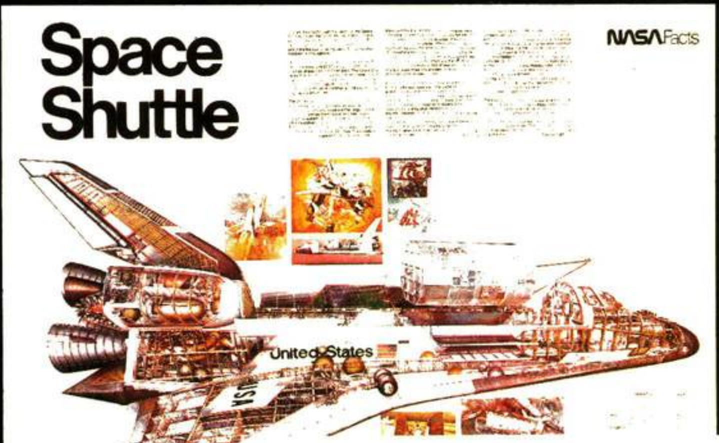

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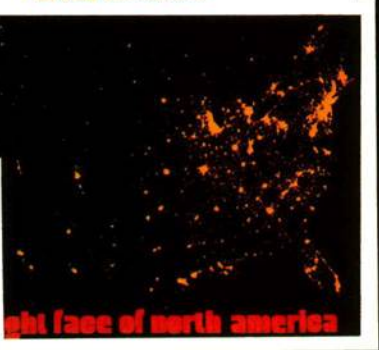

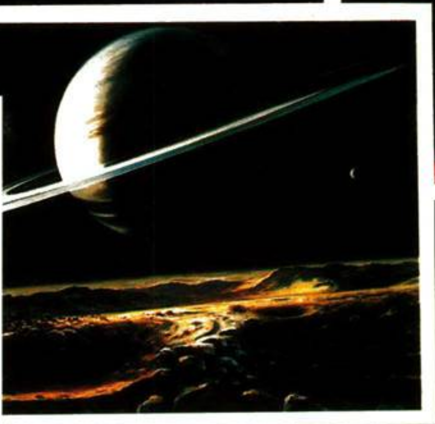

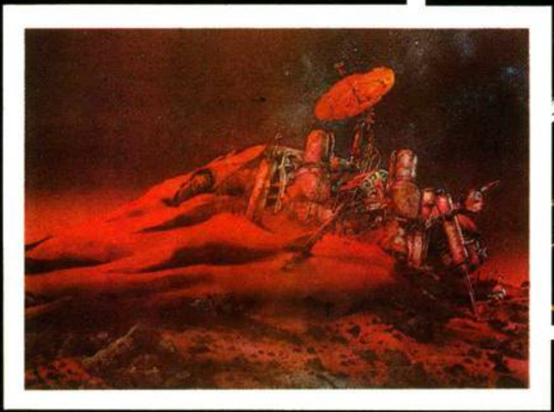

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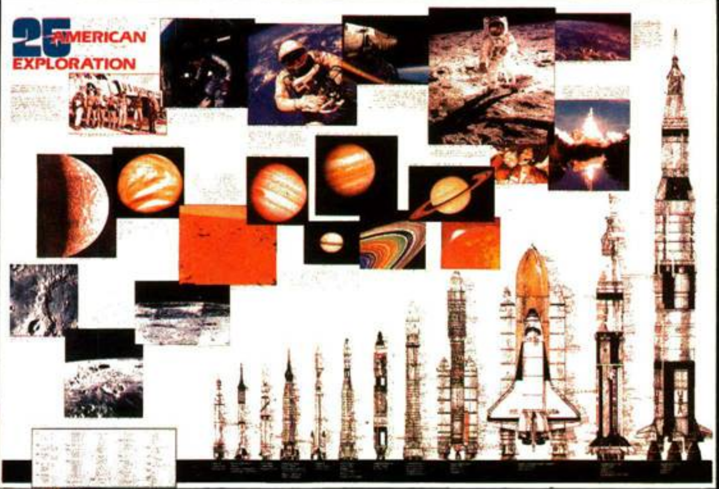

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ASTRO NEWS

Stopping Space Sickness

Space travel may seem glamorous, but there's nothing glamorous about "space adaptation syndrome." Called motion sickness on Earth, this zero-gravity malady affects nearly 50 percent of all astronauts within a day after lift-off. As space travel increases with Shuttle flights, NASA is sponsoring a number of studies on the health effects of living in weightlessness.

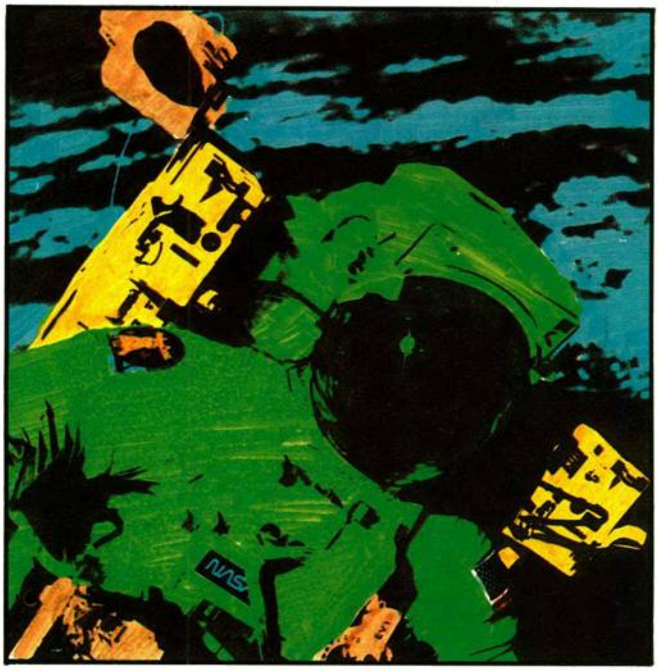
The University of California at Irvine is participating in a nationwide effort to develop treatments for combating motion sickness in space, which won't have the side effects of conventional medications. These researchers are also studying long-term effects of space travel, such as bone deterioration and muscle atrophy, with experiments planned on *terra firma* as well as in space.

"NASA has set a high priority for finding a solution to motion sickness," says Robert Blanks, associate professor of anatomy and surgery at the University's College of Medicine. "Space sickness is not life-threatening; it's considered an annoyance. But it can interfere with the efficiency of astronauts, and that's significant with tight space mission work schedules."

Blanks, who has long been interested in the inner ear and the causes of motion sickness, has been awarded a three-year NASA grant for research in developing a drug therapy that would prevent the syndrome. A drug called scopalamine is currently being used, but it has a number of side effects and must often be taken with a stimulant to counteract drowsiness.

The motion sickness problem is compounded by the fact that it is currently impossible to predict which astronauts will be affected. Some who appear highly resistant to motion sickness on Earth succumb to queasiness and vomiting in space, while others who seem likely candidates for a bout with nausea remain unaffected during space missions.

Researchers believe motion sickness is related to a number of factors: excessive visual stimulation, abnormal activity in the small intestine, and the body's vestibular system which contains the inner ear organs that allow us to perceive balance, body position, and movement. Scientists suspect the space adaptation syndrome may result from conflicting visual and vestibular signals, which then activate nerve pathways leading to the gastrointestinal tract. Nausea and vomiting are the result.



In an effort to identify the nerve systems responsible for motion sickness, Blanks and Robert Mason who chairs the Department of Surgery at the University, plan a series of anatomical and physiological experiments on the vestibular system's connection to the gastrointestinal tract. "We don't know what sends the gastrointestinal tract into reverse gear," Mason notes.

"It's conceivable that if you impair the function of certain nerves, you may totally block motion sickness. We can then identify the hormones and other substances that may play a role in inducing the response."

Once the neural pathways are known, researchers hope to identify drugs that would block motion sickness without causing equally unpleasant side effects. Of course, such medication would benefit Earth-bound sufferers of motion sickness as well.

Curing space sickness remains a top priority, but NASA officials are also concerned about long-term health effects that have been observed since the late '60s. Astronauts returning from even short flights show marked changes in body physiology. In the weightlessness of space, muscles lose mass — atrophy. Loss of fluids coupled with electrolyte imbalances could present problems in managing blood pressure when astronauts return to Earth. Bones lose calcium, mimicking the degeneration that occurs among the elderly.

Ken Baldwin is among more than two dozen scientists nationwide who are studying the potential long-term health hazards of space travel. Baldwin's studies focus on the cellular level of muscle structure and function. Though astronauts generally recover from muscle atrophy within two months after a space flight, it is not known if longer missions will result in irreversible changes in the body. "Right now this is not a major concern with NASA because we're dealing with relatively short-duration missions of seven days," Baldwin remarks. "But more prolonged exposures to zero-gravity have been proposed for the next decade."

Baldwin, who was also recently awarded a NASA grant, suspects that muscle mass reduction results from a change in the muscles' ability to develop force and use sources of energy. He believes muscles lose functional efficiency in space and drain the body's store of carbohydrates.

Baldwin is particularly interested in the function of mitochondria — the cells' powerhouses that convert carbohydrates and fats into energy. He suspects the reduced muscle activity in zero-gravity causes muscles to use the more readily available energy source found in carbohydrates, rather than the normal carbohydrate-fat blend. As a result, muscles tend to become less efficient and atrophy when required to perform less work.

Life science experiments planned for Space Shuttle missions in 1985 or 1986 should help scientists better understand the physiological changes that occur in weightlessness. "There is no doubt in my mind that if a person would take up occupancy in space the muscle system would become a vestigial system," Baldwin notes. "You really wouldn't need muscles as you do on Earth."

New "Missing-Mass" Models May Explain Galaxy Formation

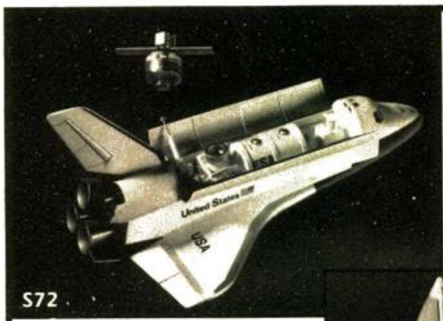
A compelling solution to one of astronomy's long-standing questions — How do galaxies form? — has been proposed by several researchers studying the properties of the invisible "missing mass" suspected to make up 90 percent of the universe. (See "Mystery of the Missing Mass," November 1984 issue.)

By assuming the missing mass is composed of sluggish, sub-atomic particles — so-called cold dark matter — the researchers calculated how material settled out as the universe expanded following the Big Bang. Their scenario, published in the October 11, 1984 issue of *Nature*, not only accounts for the different types of galaxies we know, but also their tendency to occur in certain environments, their internal characteristics, and range of sizes.

"We have produced the first explanation for the masses of galaxies, and the connection between the masses and the internal motions of their stars," says Joel Primack, University of California-Santa Cruz professor of physics. "This is the simplest dynamical property observed in galaxies and it pops right out of our calculations without any fiddling of the equations."

Besides Primack, the researchers include George Blumenthal and Sandra Faber, astronomers at U.C.-Santa Cruz, and Martin Rees of the Institute of Astronomy at Cambridge University in England.

According to the new theory, galaxies are primordial objects — the first large structures to form in the universe. Not until later do they assemble into clusters and superclusters of galaxies. This "bottom-up" model is in direct contrast to the "top-down" view, which assumes neutrinos are the *dominant missing* mass in the universe. In the top-down model, superclusters form first and later fragment into individual galaxies.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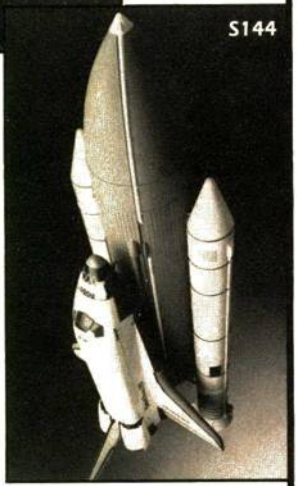
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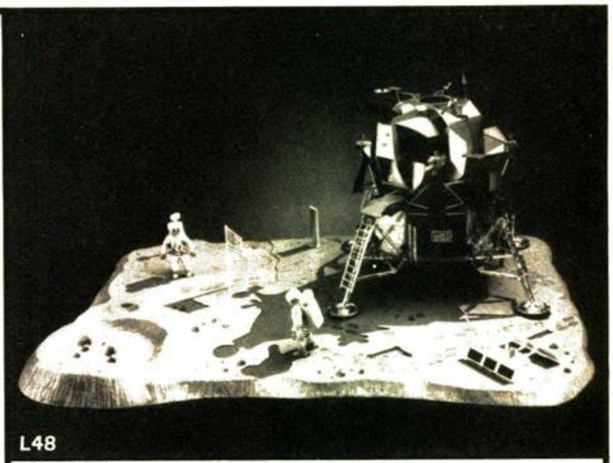
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The new calculations also explain why the two basic types of galaxy — spirals and ellipticals — have distinctive shapes and typically reside in differing neighborhoods. Spiral galaxies (like our Milky Way) are spinning, flattened collections of stars generally having few neighbors. Ellipticals are rounded, non-rotating star systems more likely to reside in a rich cluster of galaxies. "There has long been a controversy about this difference," says Blumenthal. "Is it genetics or environment?"

The answer appears to be neither alone — but rather that genetics and environment are but two sides of the same coin: the lumps destined to become ellipticals preferentially form in regions that later evolve into rich clusters. Similarly, spiral-galaxy lumps tend to form in regions that won't produce many other galaxies. The environment where spirals form is also more conducive to starting them spinning.

These explanations for galaxy types, characteristics, and environments came out of an investigation into what sort of objects could form in a universe dominated by cold dark matter.

"Cold dark matter is dark in the sense that you can't see it, and it's very cold compared to the rest of the universe, specifically the 3 K microwave background radiation," says Blumenthal. This background radiation, the residual glow from the Big Bang, is found everywhere. Candidates for cold dark matter include various "exotic" subatomic particles — predicted to exist but not yet discovered — or some types of black holes.

Scientists assume that following the Big Bang, matter in the universe was evenly distributed. In some places, though, more material than average created a locally-increased density, causing these regions to collapse under their own self-gravity and form the structures we see today.

The material we see fell into the pattern of the dark matter. By understanding how that dark matter condensed, astronomers think they have deduced how visible galaxies, composed of ordinary luminous matter, must have formed.

Several models for the dark matter have been attempted, the most popular being the neutrino-dominated models. Neutrinos, however, are "hot" matter: they moved fast — nearly the speed of light — in the early universe. When galaxy-size, high-density regions appeared in the early universe, the neutrinos in those lumps would have quickly streamed away before any collapse could occur. By the time neutrinos cooled and were moving slowly enough to settle down, they would have formed objects only the size of superclusters — nothing smaller.

Cold dark matter, by contrast, is sluggish and willing to stay put in a region of extra density. It could form the underlying pattern that allows ordinary matter to collapse into structures as small as galaxies, and early enough in time to give us the universe we see today.

"The key astrophysical idea behind cold dark matter is that if there are fluctuations in density, nothing disturbs them. Hot dark matter can't preserve small-scale, galaxy-sized fluctuations — they just disappear," says Primack. "Our theory is very predictive — that's its real success. As more data come in, we'll be able to see how well it stands up," he says.

The researchers predict that the huge voids found in the universe, enormous spaces where no galaxies have yet been spotted, ought to contain a fair number of small galaxies. The hot dark matter model predicts these voids should be entirely empty. Future observations will distinguish between the two models.

"The nice thing about cold dark matter," says Blumenthal, "is that it lets you calculate things like that. You can come up with a picture of how an individual object collapses and then make a purely statistical calculation to see how things cluster and interact."

"There's no magic and no fudge factor. The computer doesn't do anything we don't tell it to do," Primack says. "We've all been quite pleased with how well the theory has worked out."

Does Catacomb Drawing Show Christmas Star?

A drawing on the wall of a Roman catacomb may indicate that the "Star of Bethlehem," noted in Biblical accounts of the birth of Jesus, was a nova or comet observed by astronomers in 5 B.C.

Dorrit Hoffleit of Yale University Observatory came to this conclusion after an analysis suggested by artist and Biblical scholar Carolyn Murphy Beehler. Beehler had visited the Priscilla Catacomb in Rome, thought to be the oldest of the Christian catacombs, where she found a ceiling painting depicting shepherds and sheep amidst a small grove of apple trees. A closer look showed this painting was done over an earlier drawing. The original work portrays the madonna and child with a man pointing toward one of the fruits on a tree.

Beehler guessed that early Christians, facing Roman persecution, might have changed the stars to apples to avoid any religious connection. Because Priscilla was the husband of Aquila in ancient mythology, Beehler began her search for similar starfields in Aquila and was able to match the apples with stars.

She found, however, that the apple to which the man is pointing — located approximately in the Milky Way constellation of Scutum — does not correspond to any star on modern charts and contacted Hoffleit for help in making an identification.

Hoffleit discussed her findings in a recent issue of the *Journal of the American Association of Variable Star Observers* (Vol. 13, #1, 1984). She explained that if the Priscilla drawing does represent the night sky at the time of Jesus' birth, many ideas about the "Christmas Star" would have to be ruled out.

For example, several researchers suggest the star was actually a conjunction of Jupiter and Saturn in 7 B.C, but this event occurred in the constellation Pisces — far from the stars of Aquila. And, Hoffleit explained, the closest approach of the two planets was only about 1° — too great a separation to be mistaken for a single bright object.

Hoffleit noted that Venus was in the correct position to match the painting during the first months of 6 B.C., but believes the "Wise Men" — now thought to have been astrologers — would probably have been familiar with the planet and would not have mistaken it for a star.

This leaves the possibility of a nova or supernova, both of which are hard to prove this long after the fact. *The General Catalogue of Variable Stars* lists two events, one in 5 B.C. and one in 4 B.C., as recorded by Chinese and Korean astronomers. Unfortunately, the records make it impossible to establish if either was a comet or a nova. The 4 B.C. object occurred close to Altair, which means it is not the catacomb object. The position of the 5 B.C. event, however, was logged to an accuracy of about 5° and occurred about 20° from the position shown on the painting. Given the distortions of the painting's surface — and the dimly-lit conditions under which the artist worked — Hoffleit argues that perhaps a 20° error is allowable.

On the other hand, the painting must have been made long after the fact — perhaps several generations after — and the artist may have never seen the celestial event. The star's position could be based on mere hearsay or perhaps placed where it was for aesthetic or symbolic reasons.

If the 5 B.C. event was the "Christmas Star" and if it happened in this part of the sky, what sort of celestial event was it? Hoffleit feels a nova is the best candidate. Many novae have occurred in or near the plane of the Milky Way, so statistics are definitely on this side of the argument. In addition, supernovae leave a pulsar behind after they explode, and all the pulsars in that region of sky are at least 10,000 years old. *Ray Grasshoff.*

Unusual Asteroid Discovery

A fast-moving asteroid has been discovered, which is temporarily a neighbor of Earth, Venus, and Mars. The asteroid, designated 1984 QA, was discovered on August 30 by an asteroid search team made up of the Jet Propulsion Laboratory's planetary scientists Eleanor F. Helin and R. Scott Dunbar, as well as Maria Antoinetta Barucci, a visiting associate of the European Space Agency, and Caltech undergraduate Steve Swanson.

1984 QA is an exciting astronomical discovery because it is only slightly out of synchronization with the Earth. Its orbit periodically crosses the orbits of Earth and Venus, and approaches Mars. The gravitational influences of these planets on the little planetoid (about one kilometer across) make its orbit unstable. This means that 1984 QA must be a fairly recent arrival in our celestial neighborhood; it also means it will not be visiting long, astronomically speaking.

Calculations show the asteroid's close planetary encounters will gradually change its orbit, so sometime during the next 10,000 years or so, it will either impact one of the planets or be ejected from the solar system completely.

The semi-major axis of 1984 QA's orbit is closer to the Sun than that of the Earth (0.989 AU). This places it in the Aten class, named after the first of this type of asteroid, which was discovered in 1976. This is only the fourth Aten known — all of which have been discovered by Eleanor Helin during her asteroid search program. Helin has more than

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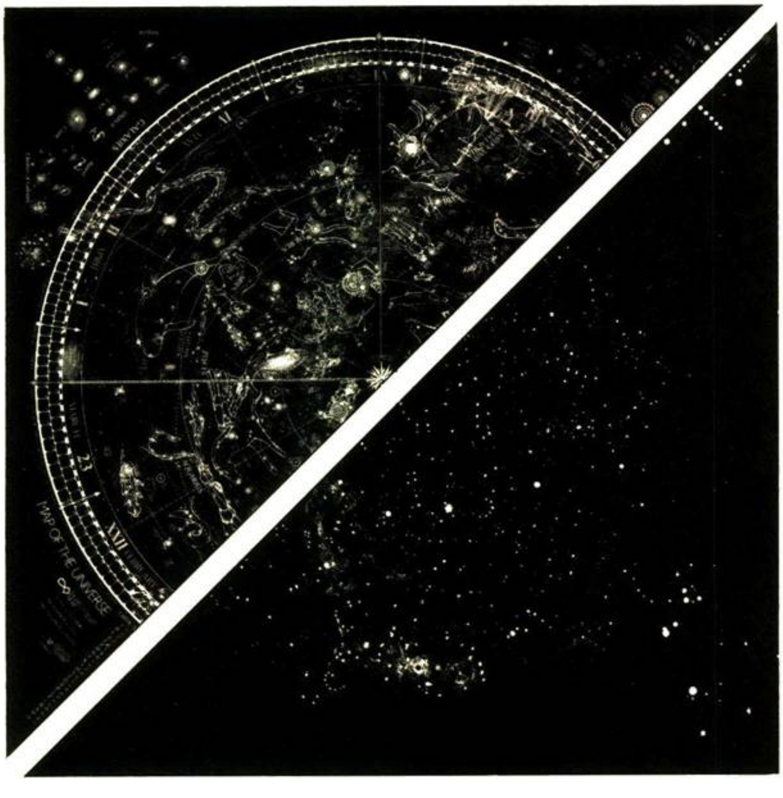

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ASTRO NEWS

20 years' experience as a planetary scientist and her program is credited with over 2000 asteroid discoveries.

The discovery of 1984 QA was remarkable not only because it is an unusual type of asteroid, but also because it is very rarely observable from Earth. The time it takes the asteroid to go around the Sun is so similar to the Earth's that the discovery circumstances are only repeated about once every 60 years. While not observed at the time, the asteroid came closest to Earth in August 1983, passing less than four million miles away. This was "a relatively close approach," said Helin.

The asteroid discovery was the result of painstaking work and some serendipity. Several days were spent at Palomar Observatory's 18-inch Schmidt Telescope taking photographic exposures and performing scans of the plates. It was Barucci who urged that just one more set of plates be taken of a particular sky area, even though the time was near dawn — not generally good for photographing asteroids. While examining these plates the next night, Dunbar spotted the faint track of the asteroid. Had the plates been exposed just half an hour later, 1984 QA would have been missed.

Between now and 1986, when it will disappear from view, 1984 QA will become increasingly difficult to observe. The asteroid will not be observable again until around 2040.

ASTRO CALENDAR

February 15-17
First Annual Winter Star Party, Everglades National Park, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Richard Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

March 29-30
The Wisconsin Society of Science Teachers Annual Spring Convention, Madison, Wisconsin. Contact: Bruce G. Smith, WSST, 1017 E. Lindbergh St., Appleton, WI 54911.

April 11
Third Annual Space Awareness Day, Commerce, Texas. Hosted by the East Texas State University Science Fact-Science Fiction Society. Contact: Dr. John Lamb, Jr., 2812 McCarley, Commerce, TX 75428.

April 12-13
1985 Southwestern Association of Planetariums Conference, Fort Worth, Texas. Contact: Michael P. Walker, Planetarium Specialist, Noble Planetarium, Fort Worth Museum of Science and History, 1501 Montgomery St., Fort Worth, TX 76107. Phone (817) 732-1631, ext. 409.

April 18-21
National Convention of the National Science Teachers Association, Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington, DC 20009.

April 20
39th Annual Convention of the North Central Region of the Astronomical League, Fermi National Accelerator Laboratory, Batavia, Illinois. Sponsored by the Naperville Astronomical Association. Contact: Deena R. Joslin, 1985 NCRAL Convention Chairman, 959 W. Ogden Ave., Naperville, IL 60540. Phone (312) 355-5357.

April 27
Astronomy Day. For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

April 27-28
Abell Memorial Weekend (in memory of George Abell). Teacher's workshop and public lecture series on new developments in astronomy. Jointly sponsored by the A.S.P. and U.C.L.A. Contact: Andrew Fraknoi, Abell Workshop, A.S.P., 1290 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

May 15-19
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP '85, Dept. A, 128 N. Commerce, Burleson, TX 76028.

May 22-24
IAPPP Big Bear Symposium, Camp Oaks, Big Bear Lake, California (same location as Riverside Telescope Maker's Conference). Contact: Rev. Donald L. Rohe, 957 W. Marshall Blvd., San Bernardino, CA 92405. Phone (714) 383-4731 or (714) 883-7923.

May 24-27
Riverside Telescope Maker's Conference, Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92505. Phone (714) 689-6893.

May 25-29
Planetarium Association of Canada Biennial Conference, Toronto, Canada. Contact: Chris Sasaki, Conference Registrar, McLaughlin Planetarium, 100 Queen's Park Crescent, Toronto, Ontario, Canada M5S 2C6.

June 7-8
15th Annual Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History. Contact: Chairman, Apollo Rendezvous, P.O. Box 20268, Dabel Branch, Dayton, OH 45420.

June 9-12
Southeastern Planetarium Association Annual Conference (professional conference), Land Between the Lakes, Kentucky. Contact: Doug Gegen, Conference Coordinator, Visitor Center, Land Between the Lakes-TVA, Golden Pond, KY 42231. Phone (502) 924-5602.

June 17
3rd American Workshop on Cometary Astronomy, Tucson, Arizona. Contact: Steve Edberg, Jet Propulsion Laboratory, 4800 Oak Grove Dr., MST 1166, Pasadena, CA 91109.

June 23-27
Astronomical Society of the Pacific Meeting, Flagstaff, Arizona. Contact: Andrew Fraknoi, A.S.P., 1290 - 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

June 28-July 1
Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, c/o Edmonton Space Sciences Centre, 11211 - 142 St., Edmonton, Alberta, Canada T5M 4A1.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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ANNOUNCEMENT — The Black River Astronomical Society invites everyone in Lorain and surrounding counties to attend their monthly meetings, which are held in the Lorain MetroPark Visitor Information Center on the first Wednesday of each month at 7 p.m. The Society has a working observatory. To receive our newsletter and information about the Society, contact Stephen Smith, 3701 W. 143rd St., #36, Cleveland, OH 44111.

ANNOUNCEMENT — The SE Michigan Amateur Astronomer computer BBS, written for the TI 99/4A, is accessible to the general public as a free, non-profit service for astronomy bulletins, events, files, and related information. Modem settings are: 300 baud, 7 bit word length, 1 stop bit, full duplex, no parity. The board has a 40 column format.

WANTED — Back issues of *Future Starlog* and magazine binders of all kinds. Contact M. Spielberg, 16 Stiles St., Elizabeth, NJ 07208.

ANNOUNCEMENT — The Auburn Astronomical Society meets the first Friday of each month at 7:30 p.m. in Room 128 of Parker Hall on the Auburn University campus. Join us for interesting programs, dark-sky observing, and other activities. Contact Russell Whigham, 123 Carter St., Auburn, AL 36830.

ANNOUNCEMENT — The Treasure Coast Astronomical Society of Stuart, Florida, invites all interested persons to attend its monthly meetings held the last Tuesday of every month at 7:30 in the Environmental Studies Center, Jensen Beach. Contact Jerry Shaw at (305) 334-5931.

ANNOUNCEMENT — The Central Florida Astronomical Society meets the second Wednesday of every month at 7:30 p.m. in the Orlando Science Center. You are invited to attend for high-quality programs of general interest. For more information, contact Diana Perry, 1624 Les Ct., Kissimmee, FL 32743. Phone (305) 933-1682.

ANNOUNCEMENT — New members wanted for the Vermont Astronomical Society. No experience required. Operating new observatory in Williston with 7" Clark refractor. Monthly meetings held at UVM's Waterman Building. Contact Gary Nowak, Club President, 23 Mansfield Ave., Winooski, VT 04501.

ANNOUNCEMENT — Free public domain astronomy and satellite computer programs for the VIC-20 and Commodore 64. Send self-addressed mailer, cassette tape or disk (specify VIC-20 or C64), and return postage to David Eagle, 7952 W. Quarto Dr., Littleton, CO 80123.

WANTED — Parts to repair 5" Clark refractor including finder, mount, and equatorial parts. Contact Charles Blumsack, 36 Commerce Way, Woburn, MA 01801. Phone (617) 935-3500.

WANTED — Morehead Planetarium seeks Electronics Technician. Experienced in electronics, repair, and maintenance of specialized electronic devices, Zeiss planetarium, automation systems, audio-visual, and micro-computers. Salary range $17,232-$25,980. Contact Employment Personnel, 111 Pettigrew, UNC, Chapel Hill, NC 27514. Phone (919) 962-2991 (EO/AAE).

WANTED — Camera Repairman (eight years experience) seeks position with Halley's Comet expedition/tour group to sub-equatorial regions. Available for the month of April 1986. Contact Jesse F. Carroll c/o Darkroom Aids Co., 3449 N. Lincoln Ave., Chicago, IL 60657. Phone (312) 248-4301 days, (312) 743-0161 evenings.

WANTED — Video cassettes of the "Cosmos" series with Carl Sagan (13 parts), VHS or Beta, will rent or buy. Call Henry Heredero collect at (305) 854-4640.

WANTED — Help from astrophotographers. If you can successfully use an Olympus camera for astrophotos, please contact Herman Meuron, 3760 Diamond Head Cir., Honolulu, HI 96815.

WANTED — 16 year old Dutch space travel enthusiast seeks correspondence with 14-20 year old American concerning space travel, exchange of materials, etc. Contact Mark Traa, Mosbeek 26, 5501 BD Veldhoven, The Netherlands.

WANTED — *SAO Star Atlas* or photocopy. Contact R.J. Kirkland, 15212-84 Ave., Edmonton, Alberta, Canada T5R 3X8.

WANTED — Correspondence with amateur astronomers living in the southern hemisphere and Europe who would like to trade ideas and observations on all aspects of astronomy. Contact David Abbou, 6115 Rose Hill Dr., Alexandria, VA 22310.

WANTED — Correspondence with amateur astronomers. Contact Thomas Tan, Commonwealth Ave., Block 27-A, #15-290, Singapore 0314.

WANTED — Opinions from owners of 4" Renaissance refractors (Tele Vue) regarding quality and function of the instrument. Contact Gail Clark, 74 Mountain Dr., Pocatello, ID 83204.

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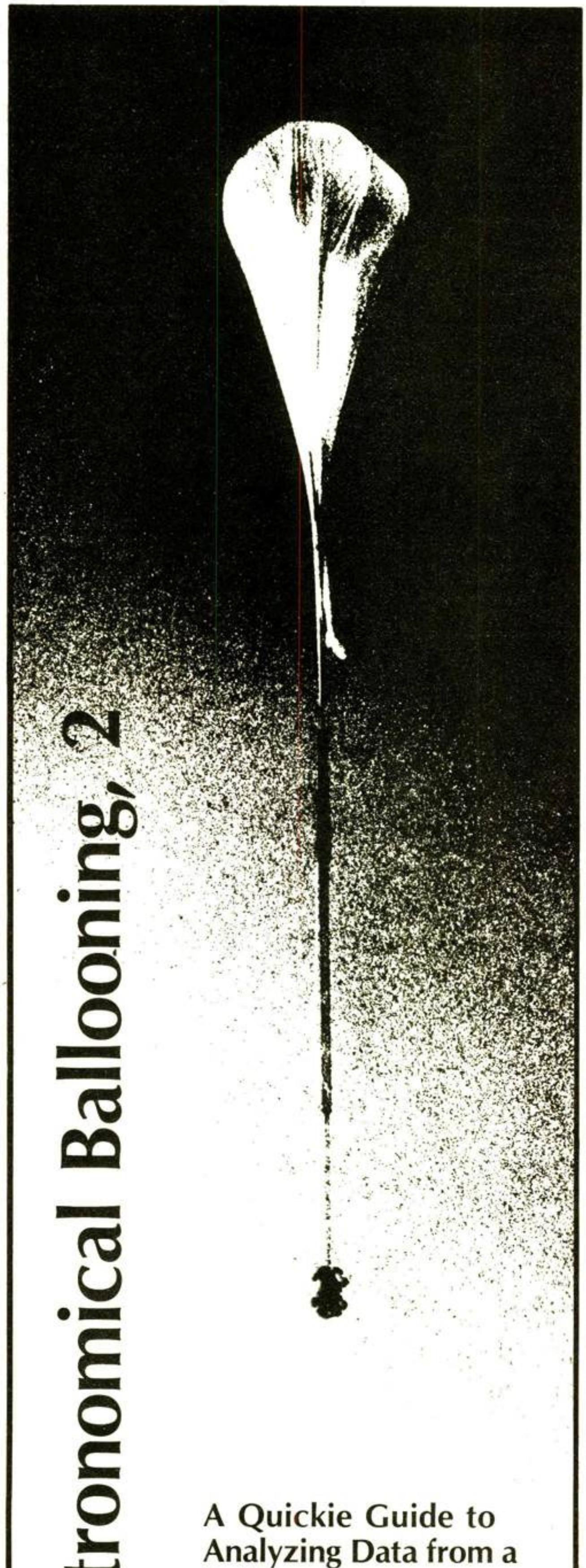
Astronomical Ballooning, 2

A Quickie Guide to Analyzing Data from a Balloon-borne Infrared Telescope

by Sten Odenwald



Last August, "Astronomical Ballooning" took you to a small town in eastern Texas for a behind-the-scenes look at what happens during the launch and flight of a balloon-borne infrared telescope. At the end of that flight, we left ourselves hanging — metaphorically, at least — with a gigantic pile of data that, in its unreduced state, was virtually meaningless. Let's pick up the story where we left off and try to make some sense out of what the instruments have recorded.

To begin with, we want our data to answer two questions: first, where is the far-infrared emission coming from; second, how bright is it?

We previously saw that a typical flight produces as much information as a full set of the *Encyclopaedia Britannica*. This information is stored as long strings of 1s and 0s, the basic alphabet of computers. To present these in their most usable form, we must construct a map of the infrared sources we've measured. These maps will form the backbone of whatever theory we — and others — propose to explain what we saw. For example, by knowing that most of the infrared emission comes from regions near the edge of a dense molecular cloud, we might be able to say something about where stars are born in these interstellar clouds. Do they favor the surfaces of these enormous clouds, or do they take shape deep in the clouds' interiors, where the density of gas is highest? Before we can come to grips with such questions, we must first attend to some fundamental details.

Where Were We Looking?

Thirty feet of film — taken during the flight by a 35mm camera bolted to the side of the telescope — tells us where our detectors, our infrared "eyes," were aimed during the 10-hour flight. As the telescope sweeps across a particular part of the sky, bright stars and planets travel through the camera's field of view, leaving their trailed images behind on the film. Throughout each 32-second exposure, a spinning shutter breaks these trails into segments. Since we know precisely when we began the exposure, measuring 15 points along every trail lets us determine where the telescope was pointing during each scan. From this, we can produce a list of star positions at each of 15 particular moments.

At this stage, the star positions are merely a set of internal coordinates established by the measuring instrument. To translate these into right ascension and declination, we have to find the positions of each of the stars from a star catalogue. These reference star positions, together with measurements of the star trails, are then processed by a VAX 11/780 computer to determine the actual right ascension and declination of the center of the camera field at seven discrete instants during each scan.

But there's a small complication: the optical axis of the camera is not always the same as that of the telescope or detector. To find out where each detector was actually pointing, we select a bright planet — such as Mars or Jupiter — which is a strong infrared source and whose trail we can measure on the film. We then check to see when each detector showed the strongest signal. This tells us when the planet crossed the center of the detector's field of view. Once we know this "peak signal time," we can combine it with the planet's trailed image on the film to calculate where each detector was pointing relative to the center of the camera's field of view.

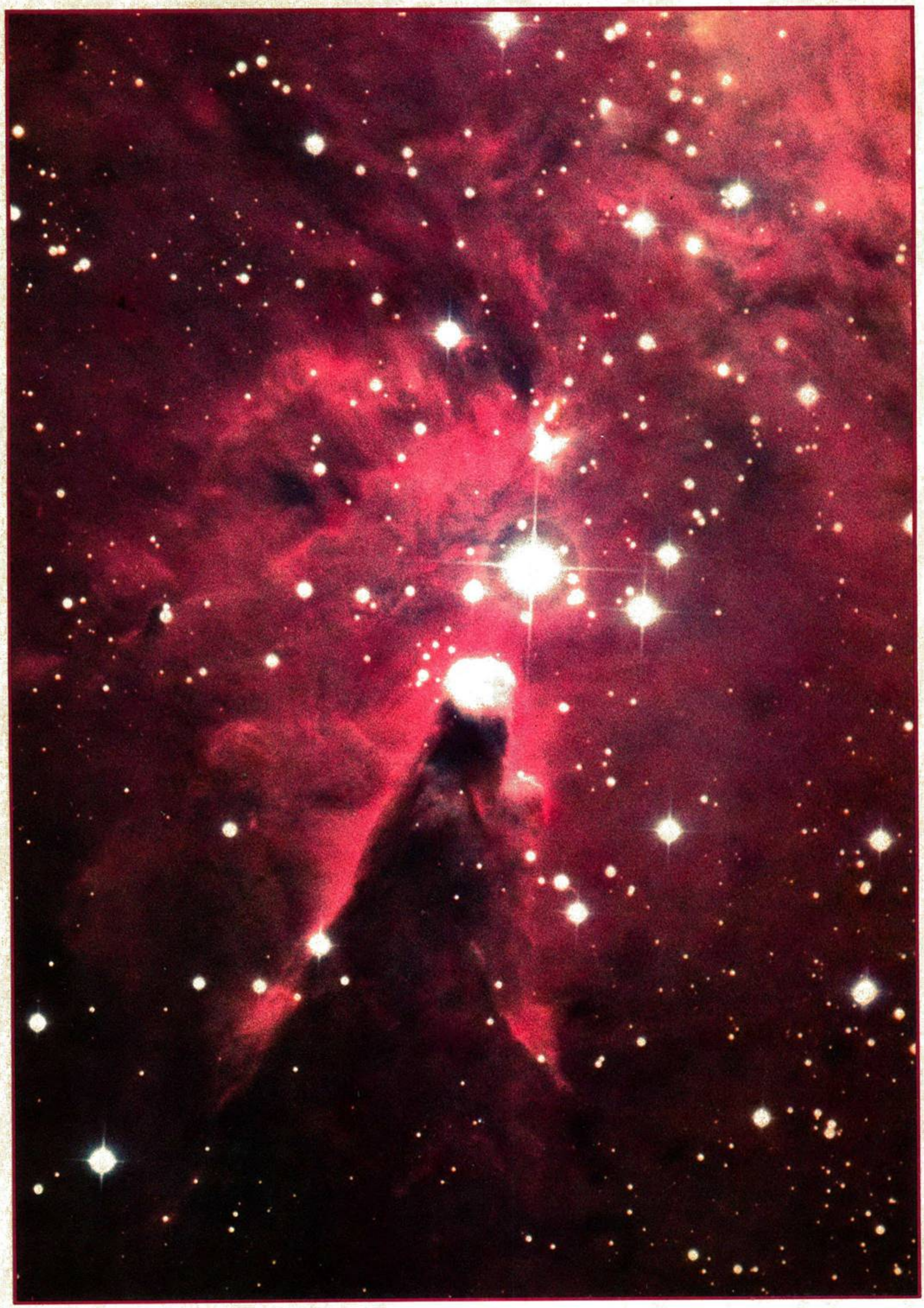
The last step is to take this information and work up a mathematical equation to represent the "aspect data" more compactly. The equation also lets us interpolate to find positions for times other than the basic seven instants. A typical scan might be reduced to look like this:

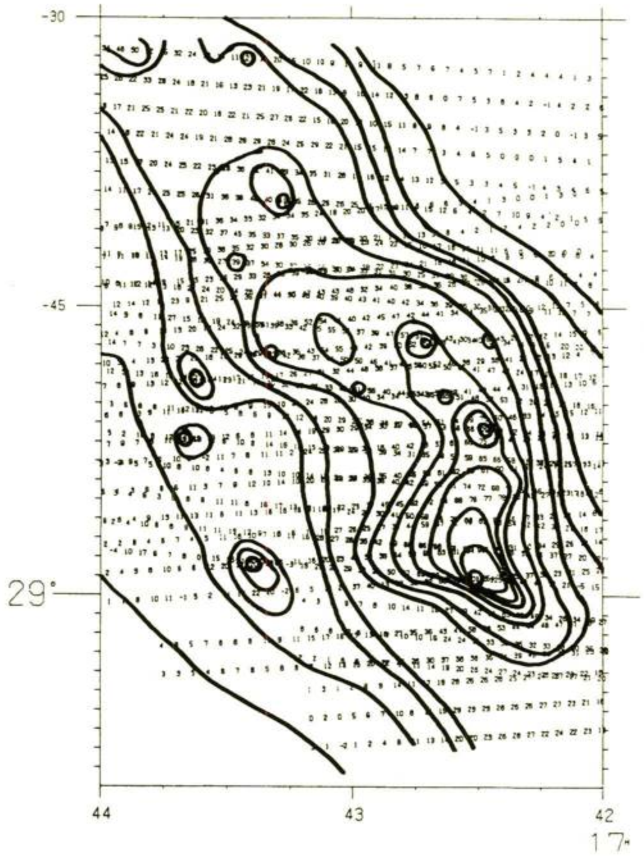
$$\text{RA (1950.0)} = 6.268\text{h} + 0.00197t - 0.00000084t^2$$

$$\text{Dec (1950.0)} = 173.83^\circ - 0.11600t + 0.0000186t^2,$$

where t is the time in seconds since the start of the hour. All the scans that form a single, 32-line raster are analyzed in this

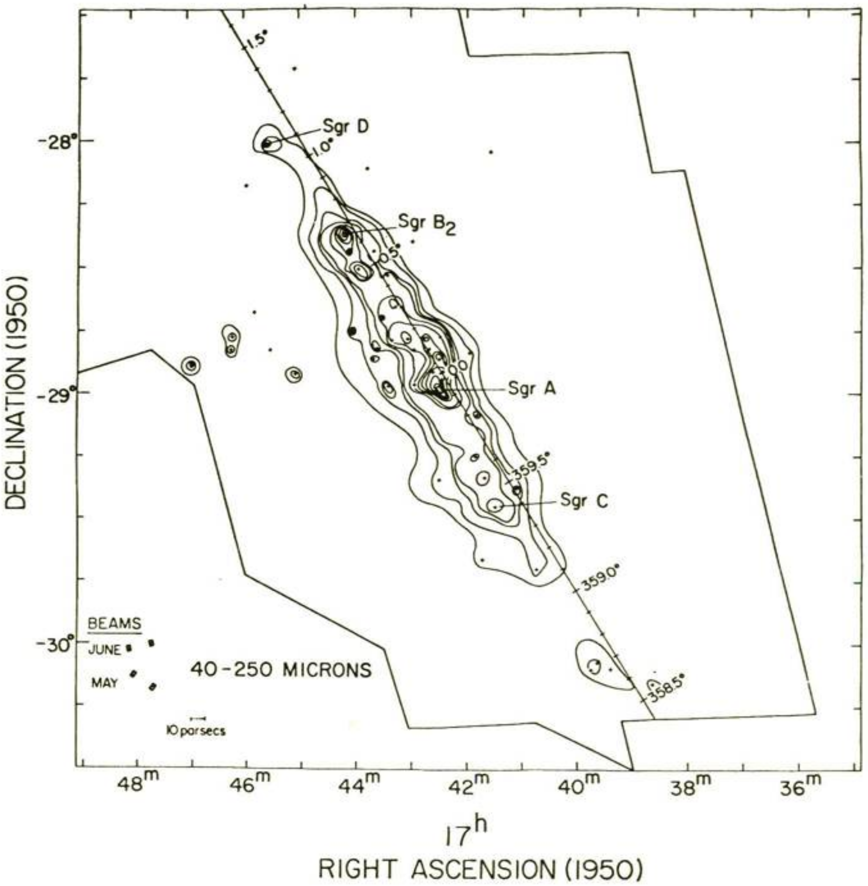
The Cone Nebula (NGC-2264) in Monoceros occurs in a region rich in dark dust and bright-red ionized hydrogen; it is visible in medium-to-large backyard instruments. Infrared astronomers study places like this, seeking clues to how stars form within them. Photo © 1981 by the Anglo-Australian Telescope Board.

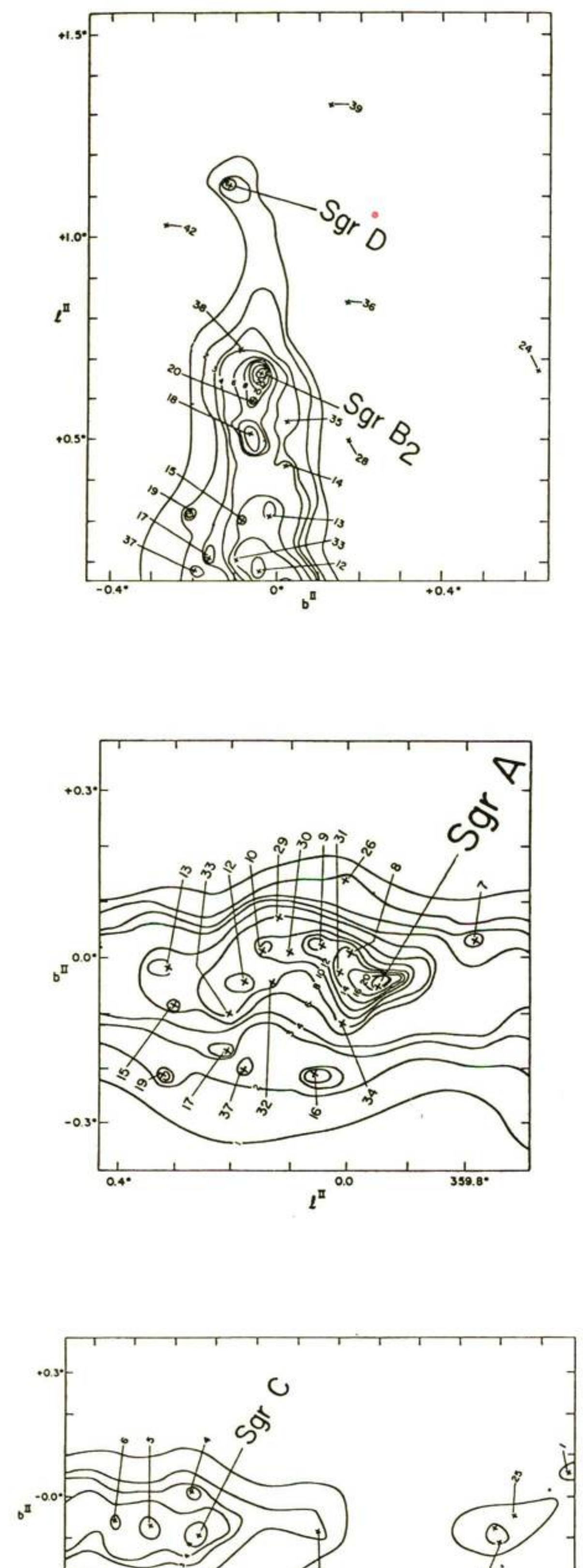




The raw data return from the balloon telescope in the form of detector voltages recorded at specific times. Combining these with simultaneous star-trail photos lets astronomers assign the voltages to actual areas in the sky. Processed by computer, the output forms a celestial grid with lines of numbers running across it (left). The astronomer then draws contours on the grid to enclose areas of equal voltage.

Several scans are combined, calibrated, and replotted more neatly to produce a finished contour map ready for publication (below). At right are maps detailing small areas of interest. Sgr A (Sagittarius A) is the core of the Milky Way Galaxy. (Illustrations on these pages courtesy of the author.)


1.5°
Sgr D
1.0°
Sgr B$_2$
0.5°
Sgr A
359.5°
Sgr C
359.0°
358.5°
-28°
-29°
-30°
DECLINATION (1950)
BEAMS
JUNE
MAY
40-250 MICRONS
10 parsecs
48ᵐ
46ᵐ
44ᵐ
42ᵐ
40ᵐ
38ᵐ
36ᵐ
17ʰ
RIGHT ASCENSION (1950)



way. Once we can pinpoint where our detectors were pointing in the sky at a given time during the observing run, we can proceed to the next stage.

What Did We See?

Even at an altitude of 18 miles, Earth's atmosphere is still not completely transparent. To far-infrared eyes, the rarefied atmosphere at 95,000 feet produces a glowing haze against which it is impossible to see more than a handful of the brightest infrared sources in the sky. The telescope's mirror also contributes to the problem since it is "warm" (about 77 K), and therefore lays its own background noise on top of the weak emission received from celestial sources.

To get around these problems — common to all infrared astronomers — observers have come up with an ingenious solution: Instead of letting the telescope stare at one part of the sky while straining to detect an extremely weak signal, we first let it measure the infrared brightness at the position of the source and then slightly tilt the secondary mirror to measure an adjacent part of sky. Subtracting the pure sky measurement from the sky-plus-source measurement yields a remainder which is the weak signal from the source itself. We call this technique "chopping" and set our instruments to do it 16 times a second. Chopping lets us detect sources whose signal exceeds the background noise by less than one part in a thousand — sources undetectable if we tried to sense them directly.

Unfortunately, a small but annoying price has to be paid. Because we are working with the far-infrared emission from two nearby points in the sky, it is virtually impossible to study any faint source that is larger than the separation between the source and background position. The surface brightness of such sources can be extremely uniform, so it contributes almost equally to the radiation measured at the source *and* reference positions. Thus it's easy to subtract an extended source right out of your data! The most obvious solution — taking the reference sky measurement farther away — often doesn't work because the sky's brightness differs if you go very far. The problem is a ticklish one and sometimes determines the kinds of objects we can study.

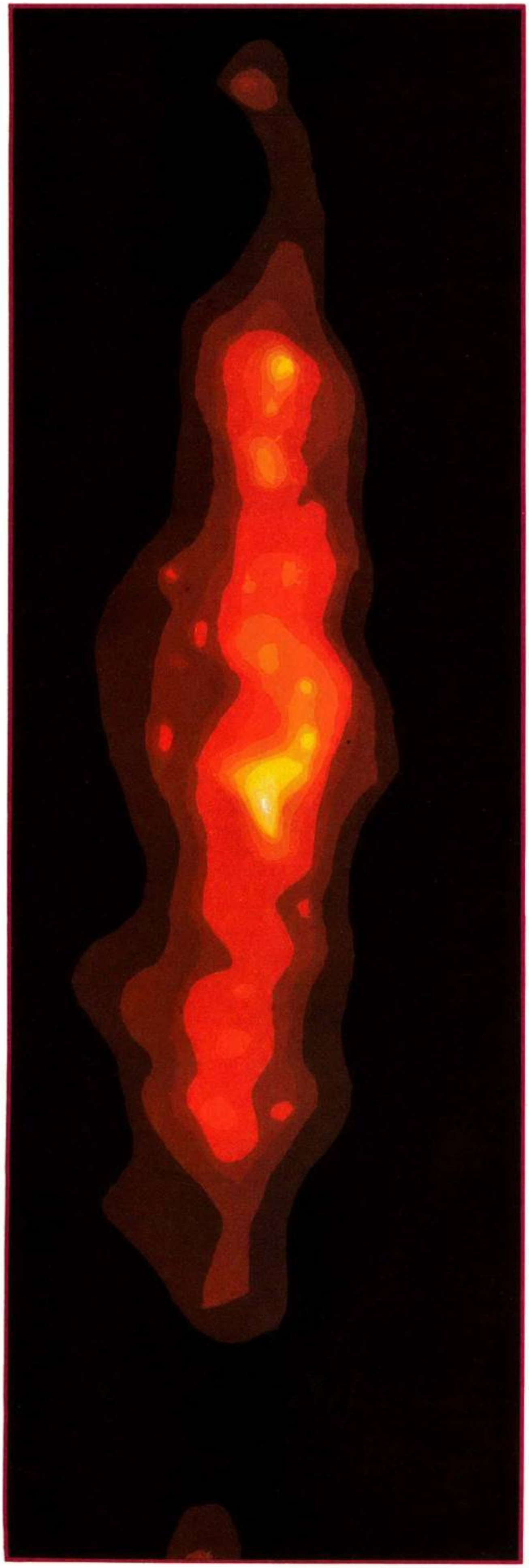
The voltage from each detector is amplified 90,000 times and forms a 16 cycle-per-second square wave which represents, alternately, the intensity of the source and then that of the background. The voltages are digitized aboard the balloon, then radioed to a ground station where they are recorded on magnetic tape in 10-bit computer words. A 10-bit word lets us break down the detector voltages into 1024 separate brightness levels. Back at the lab, a computer reads each data tape, subtracts the source and background measurements, and averages them over ⅛-second intervals throughout the flight. Once we identify the sections of data which correspond to our objects of study, we process the averaged data a third time to combine it with the positional information. The result represents the intensity of each point in the sky that we observed during our flight.

Where's the Flux?
or,
When Does 735 = 0.0000000012 Watt/Meter^2?

When we know the sources' raw brightnesses and their positions, we can plot the numbers on a sky map. We then hand-draw a set of contours on the map, enclosing regions having the same brightness levels. This contour map will eventually appear in the research paper we'll publish in a professional journal.

But to present our results in a form that has physical meaning and which other astronomers can compare with their own data, we must translate brightness levels from the arbitrary internal language of voltages into a number representing the actual amount of radiation that fell on the telescope. This quantity is called the "flux" and is customarily expressed as so many watts of power falling on each square meter of mirror. The process of converting voltages to watts/meter^2 is called calibration.

To calibrate our intensity measurements, we select a bright object whose spectrum is accurately known. For instance, during a recent flight we used Mars. A mathematical model of how the planet's surface responds to being heated by sunlight tells us the martian surface temperature, at the time we observed it, was



Line-contour maps convey much information, but require close attention to be understood. Color is more than aesthetic: it encourages you to compare individual areas and makes "global" relationships stand out. Art by Thomas L. Hunt; after S. Odenwald and G. Fazio.

241 K. (The amount of radiation given off by Mars varies as the planet's distance from the Sun changes.)

To calculate how bright the planet appeared to the detector, we need to know one last important detail: the response curve of the detector. This curve tells how efficient the detector is at sensing radiation at various wavelengths. For example, the human eye is a detector but can sense radiation only at wavelengths between about 0.4 and 0.7 micrometer. Its peak efficiency occurs at 0.57 micrometer (where much of the Sun's radiation appears). In the laboratory, we can determine a similar response curve for our detector. A computer then calculates how bright a 241 K blackbody will appear to our detectors, given the limits of their response curve and how far away Mars was at the time of observation. The calibration program also tells us how much of the total radiation produced by a source was missed when we confined our attention to a narrow part of the spectrum.

In ths example, our far-infrared detectors — sensitive to radiation between wavelengths of 40 to 250 micrometers — detected only seven percent of the radiation emitted by Mars. Carefully studying the data, we discover that a voltage of 735 units at the medium-gain setting corresponds to a flux of 0.0000000012 watt/meter^2. With slight modification, we can use this number to set the scale for all other sources we looked at during that observing run. (Incidentally, at the highest gain setting, our 1-meter telescope and its detectors can just sense a flux of $2x10^{-12}$ watts/meter^2. This is about as much warmth as you'd feel from a 100-watt light bulb 60 miles away.)

How Long Does It Take?

From start to finish, the entire process of analyzing the data takes several months; on occasion, it can take the better part of a year if other research has to be conducted at the same time. Unlike amateur astronomers, professional astronomers rarely have the luxury of working on a single topic full time, but must often divide their attention among several research projects in various stages of completion. You'd be surprised how many astronomical papers get their start as an astronomer is flying on a commercial jet between observatories!

A typical week's schedule might look like this:

Monday. Work on balloon data from the flight last April.

Tuesday. Work on the *Astrophysical Journal* article about supernova remnant IC 443, based on observations made at the VLA last January.

Wednesday. Work on the VLA maps of the galactic center far-infrared sources observed last April.

Thursday. Work on the radio source survey to finish the first draft of research paper.

Friday. Analyze the carbon monoxide observations of galaxies M-108 and NGC-4088 made last March.

And the whole thing might change again next week, when you find yourself hot on the trail of some new discovery suggested by your data. In addition, many weeks are taken up during the year carrying out new observations — or planning next year's balloon flights for the far-infrared telescope. Astronomers usually have a backlog of old data waiting to be analyzed and written up for publication.

It sounds — and is — like a frantic, endless round of hurry-hurry. But unless you've done it, you can't know the tremendous sense of excitement of going to work on a Monday with data about the star-forming regions in our Galaxy — then on Tuesday, wrestling with understanding what's going on inside the nucleus of a galaxy millions of light-years away. Sure it's crazy, but I can't think of any other work I'd rather do.

Sten Odenwald is an infrared astronomer at the Naval Research Laboratory in Washington, DC. His research interests include studies of the far-infrared properties of giant molecular clouds and young star-forming regions in the Galaxy.

ASTROMART

WANTED — 1¼" rack and pinion focuser for 2.5" refractor, 2⅜ I.D. tube. Have for sale or trade 6" f/8 mirror with mount and diagonal, 1¼" Barlow, 1¼" focuser for reflector, Minolta Auto Bellows III, and *Sky & Telescope* back issues (June 1968-June 1969). Contact Neil Schaming, 5121 Interboro Ave., Pittsburgh, PA 15207.

WANTED — Correspondence with individuals interested in space development; also newspapers, magazines, and books on the subject. Contact Masaaki Nishizawa, Koonanso, Sakuradi 2-Chome, No. 29, Nerima-Ku, Tokyo 176, Japan.

WANTED — 20"-24" mirror figured to f/6, Cassegrain hole desired. Send description to Jeffrey L. Hunt, P.O. Box 7, North Aurora, IL 60542.

WANTED — Photographs of comets taken by amateurs for a book to be compiled in the near future. All pictures welcome. Contact Mr. S. Broadbridge, 13 St. Ursula Grove, Southsea, Portsmouth, Hampshire, England.

WANTED — Information on the U.S. and Russian space programs, and the Chinese Sharpei. Contact Marty Nealeigh II, 2943 Sunset Dr., New Braunfels, TX 78130.

WANTED — 16" or larger Newtonian with low f/ratio, mount, and drive for short-exposure astrophotography. Meade DS-16" or comparable scope preferred. Contact Kenneth Ung, 163B Starr Rd., Cheswick, PA 15024. Phone (412) 265-5177.

WANTED — Newspaper articles about Space Shuttle flights and past space flights such as Mercury, Gemini, Apollo, Viking, etc. Will trade for other space material or will buy. Contact Michael Nadeau, 192 Therrien St., Ste-Anne Des Plaines, Quebec, Canada, J0N 1H0.

WANTED — 1¼" Huygenian or Ramsden eyepieces for solar observation. Would prefer 20mm or shorter, but any size is acceptable if in good condition. Age not important. Contact Kevin Redden, HC 73, Box 736, Vanceburg, KY 41179.

WANTED — *The Explanatory Supplement to the Astronomical Ephermeris and American Ephermeris and Nautical Almanac*. Contact Mark Whiteman, 314 Mullica Hill Rd., Glassboro, NJ 08028.

WANTED — Correspondence with anyone interested in space flight to exchange periodicals, books, and information on local and worldwide events. Contact Robert Sutton, 94 Tonar St., Northcate, Auckland 9, New Zealand.

WANTED — Solar filter for Celestron 8. Phone Arlene Buckler at (301) 326-2691.

WANTED — Correspondence with persons interested in radio astronomy of short-wave band 1.600-30.0 MHZ ranges. Contact WDX461 Monitoring Station, 2831 Dupont St. South, Apt. 9, Gulfport, FL 33707.

WANTED — Someone who will modify the shutter mechanism of my 35mm and 60mm format SLR cameras (Nikon and Hasselblad). Will also consider having entirely new cameras designed and fabricated with vibration-free shutters at the focal plane. Will cover all costs. Contact Jacques Guertin, 35626 Lundy Dr., Newark, CA 94560. Phone (415) 855-2018.

WANTED — Amateur astronomer plans to visit the U.S.A. during January/February 1986. Would like to meet as many U.S. amateurs as possible. Main interests are solar system objects and seeing the northern galaxies. Contact Maurice Clark, 5 Taylor St., Tambellup, 6320 Western Australia.

WANTED — Very low priced back issues of ASTRONOMY Magazine. Any number or condition of issues accepted. I'll cover postage. Contact Mike McLaughlin, P.O. Box 125, West Peru, ME 04290.

WANTED — Coulter CT-100 4¼" with equatorial mount, slow motion controls, and any other accessories. Contact Wayne E. Christensen, 4569 Ahuli Pl., Honolulu, HI 96816. Phone (808) 734-8677.

WANTED — 14-year-old amateur telescope maker seeks Sphereometer and other testing equipment for telescope mirrors and lenses. Funding limited. Contact Ian Storey, 42 Grosvenor Rd., South Shields, Tyne & Wear, NE33 3QG, England.

WANTED — In Hawaii (to avoid shipping costs), reflecting telescope 8" or larger, prefer Meade. Contact Terry Welch, 2600 Pualani Way #2403, Honolulu, HI 96815. Phone (808) 922-3596.

WANTED — Celestron 3" off-axis solar filter for C-8. Also TeleVue 4.8mm Nagler. Please write indicating price and condition. No damaged goods. Will consider best offer in month of ad. You pay shipping. Contact R.M. Harris, 2111 Wisteria Rd., Macungie, PA 18062. Phone (215) 395-8809.

WANTED — Designs, drawings, information, and plans on the following: phonemodems, keyboards, printers, disk drives, and anything else concerning computers. Contact Marty Nealeigh II, 2943 Sunset Dr., New Braunfels, TX 78130.

WANTED — VHS copies of *Cosmos* (entire series or individual episodes) and *Star Trek*. Contact Tim Baumann, 2109 Floyd, Iowa Falls, IA 50126.

WANTED — Any and all information about MSX and Spectravideo computers from newsletters, retailers, users, groups, etc. Contact G. Vigneault, P.O. Box 5524, Stn. A, Toronto, Ontario, Canada, M5W 1N5.

WANTED — October 1973 back issue of ASTRONOMY and December 1983 issue of *Science 83*. Must be in good condition. Contact Duane Davis, 12394 E. Arizona Dr., Aurora, CO 80012.

WANTED — HP-85A owners interested in swapping programs. Contact Greg Spryn, 8726 Hayshed Ln., Apt. 101, Columbia, MD 21045.

WANTED — Celestron Sky Grabber. Contact Bob Mason, Route 13, Box 825, Lake Charles, LA 70611. Phone (318)-855-6161.

WANTED — Space/astronomy and glacier/ice age slides, photographs, or other information — needed for a college research paper presentation. Contact Chris Obert, 20 S. Porter St., Bradford, MA 01830.

WANTED — Library seeks donations of back issues of ASTRONOMY. We need full year sets from 1973-1981. Donor's name will be placed in books. Contact S. O'Neill, 325 Highland Rd., Pittsburgh, PA 15235.

WANTED — Information concerning the performance (including optical, mechanical, and photographical) of the Meade 1080 8" and/or Celestron C-8 telescopes. Contact Doug Close, 808 Hummel Ave., Lemoyne, PA 17043.

WANTED — Back issues of *Mercury* magazine, preferably a complete run from Volume I to Volume XI. Contact Jeffrey K. Wagner, 566 Main St., Vermillion, OH 44089-1087.

WANTED — Questar or Quantum telescope for teacher. Send particulars to G. Lietz, 1527 Lincoln St., Evanston, IL 60201. Phone (312) 328-5476.

WANTED — Professional and amateur astronomers interested in writing articles for college astronomical society magazine, *Cosmos Chronicle*. Articles can be of any length, preferably typed. If interested, contact Paul Allen, 7 Wood Terrace, South Shields, Tyne & Wear, NE33 4UY, England.

WANTED — Used 16" deep-space telescope. Will purchase cash or trade shortwave radio, YAESU-FRG-7000 — New $750. Contact Jim Gencarelli, 189 E. Broadway, New York City, NY 10002. Phone (201) 573-1304.

WANTED — October 1973 back issue of ASTRONOMY, hard-bound astronomy-related books, inexpensive telescope. Contact C. Bufano, Rural Route 4, Box 4146, Shelburne, VT 05482.

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WANTED — ASTRONOMY back issues: September 1973-August 1974, October 1974-April 1975, and January 1976. Must be clean and complete. Best offer accepted. Contact George Burckhartt, 1810 Whiteman, Butte, MT 59701.

WANTED — Books, records, tapes, newspapers, magazines, memorabilia, etc. concerning the American and Soviet space programs. Contact George Paulson, 609 Homestead Ave., Peekskill, NY 10566.

WANTED — People to exchange NASA and industry documents pertaining to the American manned space program. Send your list. For my list of nearly 1000 titles, send a business-size envelope with 40¢ postage. Contact Russ Tobias, 1061 Second St., Santa Rosa, CA 95404.

WANTED — Help in converting programs found in *Pocket Computer Programs for Astronomers* by Fred Klein to run on Radio Shack's PC-2 computer. Contact Jack Huerkamp, 20 N. Blueridge Ct., New Orleans, LA 70128. Phone (504) 246-2587.

WANTED — 3" or 4" refractor of good quality in good condition. Contact Albert Nye, P.O. Box 1000-6, Montgomery, PA 17752.

WANTED — Correspondence with any amateur/professional astronomers interested in theoretical astronomy. Contact Rodulfo-Luigi F. Morosi, 1079 J.P. Rizal, Makati, Metro Manila 3116, Philippines.

WANTED — Anything concerning the "Space Flight Participant Program" that NASA is gearing up for, to fly civilians aboard the Space Shuttle. Photos of the Soviet shuttle also wanted. Contact Jacob

WANTED — Have B.S. and M.S. degrees in Astronomy from Penn State University. Am looking for planetarium, observatory, or other job opportunities in astronomy. Contact Samuel Dietze, 417 23rd Ave., Altoona, PA 16601. Phone (814) 943-7384.

WANTED — Low priced ASTRONOMY back issues before July '84 for young astronomer and struggling student from "Down Under." If you can help, contact or send issues to Darren Kelsall, R.D. 2, Mangonui, North Island, New Zealand.

WANTED — *Sky & Telescope*, October 1954; June-August, October, and November 1955; January, April, July, September, and October 1956; January, May, August, and November 1957; February-April and October-December 1958. Contact Gary Peterson, 14396 30th Ave. N.E., #308, Seattle, WA 98125.

WANTED — Information on how to build an image intensifier. Contact Shane Johnston, Route 1, Box 189, Calvert City, KY 42029.

WANTED — 17 year old interested in becoming a professional astronomer would like information. Contact Terry Debono, 3633 82nd Ave., NW Springtree, Sunrise, FL 33321.

WANTED — Any information concerning astronomy-related clubs in the Dallas, Texas area (prefer Carrollton vicinity). Contact Lynn Borel, 2806 Lakeside Ln., Dallas, TX 75006.

WANTED — Science Center/Planetarium seeks donations of telescopes and other astronomical equipment. Tax-deductible receipt furnished upon request. Contact Walker County Science Center, Box 10, Rock Spring, GA 30739. Phone (404) 764-1111.

WANTED — Questar 7. Send particulars and price to Charles Blumsack, 36 Commerce Way, Woburn, MA 01801. Phone (617) 935-3500.

FOR SALE — Mead DS-16 equatorial mount with motor drive and 40 lb. counterweight, $500 plus shipping. Contact John Dotton, 2605 SW 69th, Oklahoma City, OK 73159.

FOR SALE — Hewlett-Packard 41c calculator with the following modules: quad memory, extended functions, PPC custom, and HP-IL control. Lists for $540, will sacrifice for best offer over $325. Contact Michael DeZearn, 2529 Parliament Dr., Abingdon, MD 21009.

FOR SALE — Original Goodwin Barlow lens, 1¼" diameter, adjustable 1x to 3x, $40; 28mm orthoscopic research-grade Meade eyepiece, $35; 12.5mm orthoscopic eyepiece, $20. Contact David Clemens, 251 Perkiomen Ave., Schwenksville, PA 19473. Phone (215) 287-7716.

FOR SALE — Sacrifice — giant 30x80 Celestron deep-sky binoculars. Brand new. $245. Contact Mark Edelson, 747 10th Ave., New York, NY 10019. Phone (212) 247-3158.

FOR SALE — Celestron C-8. Full aperture solar filter, eyepieces (12mm, 25mm, and 40mm), Porro prism, barlow, tripod, wedge, clock drive. Perfect condition. Selling for $800 because of illness. Contact R. Baither, 510 E. 26th, Sterling, IL 61081. Phone (815) 625-2831.

FOR SALE — Spectra-Physics model 155 helium-neon LASER; 0.5 mW output power, 632.8 nm visible red light. Asking $250. Contact John St. Peter, 22531 Pembroke, Detroit, MI 48219. Phone (313) 535-2755.

FOR SALE — Back issues: ASTRONOMY, 95 copies dating back to 1978; *Discover*, 40 copies; *Science Digest*, 36 copies; *Science 83* and *Science 84*, 10 copies; *Nature*, 10 copies — all for $60 plus freight. Contact Fred Flanders, 10422 Telephone Rd., Houston, TX 77075.

FOR SALE — Meade 10" 2120, high-transmission coating, Meade tripod and wedge, dew shield, counter weights, drive corrector, 11 color filters, star diagonal, erecting prism, 5 eyepieces, trunk, and instructions. Retail value $3000; asking $1800 firm. Contact James J. Tomasko, 224 Aspen Ct., Bolingbrook, IL 60439. Phone (312) 759-3808.

FOR SALE — *Sky & Telescope*, May and September 1955, November 1956, July 1958, and January 1960; $1.25 per issue or all five for $5 (includes postage). Contact Gary Peterson, 14396 30th Ave. N.E., #308, Seattle, WA 98125.

FOR SALE — 1¼" mint condition parfocal Brandon occulars by Vernonscope (24mm, 16mm, 12mm, and 8mm); also 2.4x parfocal Dakin Barlow. $40 each or all five for $180 (payment by bank money order). Contact Robert Madison, 3425 Calhoun Rd., Beaverton, MI 48612. Phone (517) 435-9485.

FOR SALE — One-year-old Edmund 6" f/6 reflector with equatorial mount and clock drive. $375 plus shipping. Will deliver free within 100 mile radius of my home. Contact Bill Gnirrep, 217 Monroe Ave., River Edge, NJ 07661. Phone (201) 261-0975.

FOR SALE — Meade 8-inch 2080 LX-2 Schmidt-Cassegrain, mint condition, 5 eyepieces, field tripod, drive, case, and dewcap for $1200. Contact Dale Dufresne, 419 Pine St., Norco, LA 70079. Phone (504) 764-7882 after 6 p.m. weekdays.

FOR SALE — Tri-Schiefspiesler telescope, 10" f/14.7 on portable English yoke mount, no drive, $600. 5" f/1.0 Schmidt camera optics, $160. Vidisector, 40x40mm sensitive area, 1 micron resolution, in a housing, $2500. Contact George Chaplenko, 73 Alexander St., Edison, NJ 08820. Phone (201) 549-0615.

FOR TRADE — Space/NASA information, college and contractor books and journals. Send your list of information for trade to Chuck Kiesewetter, 180 Sherwood Dr., Monaca, PA 15061.

FOR SALE — *SpaceWorld*, 1974 to 1980 (62 issues, some missing); *Science Digest*, December 1980 to October 1983 (34 issues). All for $35, or send for price list. Contact Jeff Linscott, 2966 Cletus Pkwy., Lima, OH 45805. Phone (419) 991-6988.

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FOR SALE — 8″ f/5 Newtonian, three years old; fork mount with drive and 2″ focuser; good condition. Star test results very good. $700 Canadian, $525 U.S. Contact Greg Pimento, One Mourning Dove, Elmira, Ontario, Canada N3B 1E2. Phone (519) 669-1404.

FOR SALE — Meade 10″ model 2120 SCT, wedge/tripod, special coatings, enhanced mirror coatings, eyepieces, off-axis guider body, Accutrack mini-drive, tele-extender, telecompressor, LX drive, and lifetime warranty. Six months old and in excellent condition. $1850 firm. Contact Joe Firmage, 2171 Arbor Ln., Salt Lake City, UT 84117. Phone (801) 272-5972.

FOR SALE — 10.1 Coulter Odyssey compact Dobsonian telescope with two eyepieces. Still under warranty. $250. Contact Dave Borenstein, 197 Rutledge Dr., Red Bank, NJ 07701. Phone (201) 671-4185.

FOR SALE — Meade 8″ f/6 reflector model 791 with motor drive, 9mm and 25mm eyepieces, slow motion declination control, latitude adjuster, and accessory shelf. Mint condition. Asking $525. Contact Lewis Langella, 93 Hughes St., East Haven, CT 06512. Phone (203) 467-1043.

FOR SALE — 16″ f/6 Newtonian, professionally-made mounting, serious inquiries only, $12,000 or best offer. 10″ f/6 Meade research series, like new, $1100 or best offer. For photos and details, contact Fred Riemer, P.O. Box 342, Germantown, WI 53022. Phone (414) 255-9337 or (414) 255-4114.

FOR SALE — Zoom telescope (12x to 50x50) with table tripod, R160.00. Contact Mauritz J. Geyser, 345 Frederik Burger St., Erasmia (Pretoria), 0183 Republic of South Africa. Phone (012) 401152 R.S.A.

FOR SALE — Celestron C-8, special coatings, tripod, many extras, very good condition, $1150; Celestron Schmidt Camera 8″, polar alignment set, extra film cassette holder, Kencor drive, drive corrector, $1400. For details, contact J. Cole, 9205 Garfield Ct., Redford, MI 48239.

FOR SALE — Meade research series 12½″ equatorial mounting damaged in car accident; pier destroyed but equatorial head may be repairable. Best offer. Will deliver to any point along Interstate 80 free. Contact Juan Garcia, P.O. Box 2441, Los Angeles, CA 90028.

FOR SALE — C90 spotting scope with standard accessories plus Porro prism, 3x Barlow, lens shade, tele extender, Solar Skreen. All practically new; guaranteed. Valued at $550, will sell for $300 or best offer. Contact R. Sykes, 511 Main, Stevensville, MT 59870. Phone (406) 777-5333.

FOR SALE — British science and science fiction magazines including 14 volumes of *New Scientist*. Also small number of Soviet and European-related books. Contact Colin Johnston, 19 Orangefield Ave., Belfast, Northern Ireland.

FOR SALE — Schmidt camera, Celestron 8″, two film holders, roll film adapter, filter holder, $1050. Byers 812TR equatorial base, C8 fork, adapter plate, $1100. Both for $2000. Contact C. Lawrence, 200-14 Hilton Ave., Hempstead, NY 11550.

FOR SALE — *Sky & Telescope*, ASTRONOMY, and *Star & Sky* magazines from the 1970s and '80s (some *Sky & Telescope* from as far back as 1957). Will sell all for $100 or send for price list. Contact Jeff Linscott, 2966 Cletus Pkwy., Lima, OH 45805. Phone (419) 991-6988.

FOR SALE — Coulter 10.1 Odyssey Compact, excellent condition, $225 or offer. Quantum Four with all accessories including drive corrector, $850. Trades considered. Contact Gordon Jenkins, 170 Koontz Ln., #61, Carson City, NV 89701. Phone (702) 882-6456.

FOR SALE — Meade 8x50mm right-angle viewfinder without brackets. Hardly used, excellent condition, $43 post-paid. Contact Franklin Han, 1888-B Iwi Way, Honolulu, HI 96816.

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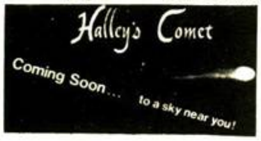
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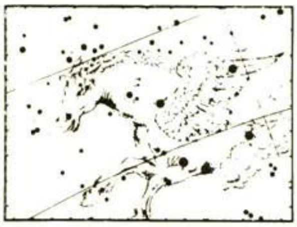
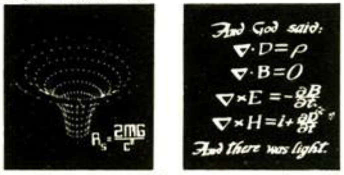
12



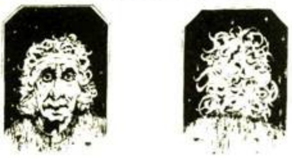
7

PEGASUS. From Johann Bayer's Star Atlas *Uranometria* published in 1603. On lt. blue, silver, or lilac shirts.


$R_s = \frac{2MG}{c^2}$
And God said:
$\nabla \cdot D = \rho$
$\nabla \cdot B = 0$
$\nabla \times E = -\frac{\partial B}{\partial t}$
$\nabla \times H = i + \frac{\partial D}{\partial t}$
And there was light.

5

Front: Black hole w/ Schwartzchild's radius.
Back: Maxwell's equations of light.



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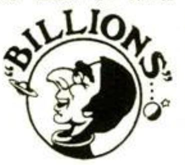

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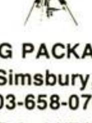

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Computing the Ephemeris of Comet Halley

Gazer's Gazette

by

Roger Browne

Everyone knows Comet Halley is coming back. But where will it appear in the sky? Of course, I knew the best way to find out where Halley would appear was to look it up in *The Comet Halley Handbook*, but I thought it would be great fun to compute it myself.

The program I wrote computes the comet's right ascension and declination, its distance from both the Sun and Earth, and an estimate of its magnitude for any date between 1946 and 2026. I found the necessary formulae in W. M. Smart's *Textbook on Spherical Astronomy* and P. Duffett-Smith's *Practical Astronomy with Your Calculator*. I originally wrote the program for a Sinclair ZX81 computer, where the program occupied only five kilobytes of memory. The version presented in this article has been modified to run with Microsoft BASIC, though nearly any BASIC executes the program, with minor modifications.

Let me warn you before going any further that this is not a high-precision program. It does not take into account perturbations in the comet's position caused by the planets, nor does it model non-gravitational effects which make comet ephemerides notoriously difficult to compute. Compared to ephemerides produced by the big machines at JPL, this program is definitely kid-stuff, but a great deal of fun to run and quite accurate most of the time.

We begin by defining Halley's orbital parameters. They are: PH, the epoch of perihelion; PL, the longitude of perihelion; AN, the longitude of the ascending node; PY, the period in years; SM, the semimajor axis of the orbit in astronomical units; EO, the eccentricity of the orbit; and IO, the inclination of the orbit. These numbers define the size, shape, and orientation of the comet's orbit in space relative to the plane of the ecliptic and the vernal equinox.

If you read up on orbit determination, you'll find that the perihelion distance rather than the semimajor axis (0.58710) is sometimes used; the two quantities can be computed from each another given the eccentricity. You'll also occasionally find a quantity called the argument of perihelion (111.85) specified rather than the longitude of perihelion. The quantity is the difference between our PL and AN quantities, so this is no problem. Furthermore, don't expect to find different sources agreeing on the exact values of Halley's orbital parameters — but there is very little difference in the ephemeris when the parameters vary in the fifth decimal place!

Lines 200 through 280 ask the date. The program first determines the number of days, N, before or after perihelion. From this we calculate the eccentric anomaly by solving Kepler's equation for line 450. The program iterates until the error in the determination is negligible. (Lost already? I recommend you study the Duffett-Smith book. For the time being, please bear with me and do the program cookbook fashion.)

Next we obtain the comet's true anomaly V in line 500, its radius vector R in line 540, the projected heliocentric longitude P in line 650, and the projected

HALLEY.BAS

```
10 REM -------- COMET EPHEMERIS ---------
20 LET PI=3.14159
30 LET CO$="COMET HALLEY"
40 LET PH=1986.11
50 LET PL=170.011
60 LET AN=58.1453
70 LET PY=76.0081
80 LET SM=17.9435
90 LET EO=.967267
100 LET IO=162.239
110 REM ---------------------------------
120 PRINT "         ":CO$
130 PRINT "- - - - - - - - - - - - - - -"
140 PRINT "    EPHEMERIS FOR DATES"
150 PRINT "   BETWEEN 1946 AND 2026"
160 PRINT "       by Roger Browne"
170 REM ---------------------------------
180 REM       Input the Date
190 REM --------------------------------
200 PRINT "INPUT YEAR"
210 INPUT Y
220 IF Y<1946 OR Y>2026 THEN GOTO 200
230 PRINT "INPUT MONTH "
240 INPUT M
250 IF M<1 OR M>12 THEN GOTO 230
260 PRINT "INPUT DAY"
270 INPUT D
280 PRINT
290 REM --------------------------------
300 REM    Calculations for the Comet
310 REM --------------------------------
320 LET X=PH
330 IF Y>=1986 THEN LET Z=1984
340 IF Y<1986 THEN LET Z=1988
350 IF Y>=1986 THEN LET S=0
360 IF Y<1986 THEN LET S=1
370 GOSUB 1780
380 LET DS=N
390 LET B=(360/PY)*(N/365.25)
```

radius vector R2 in line 660. These quantities tell us Halley's location in space — how far around, how high above the ecliptic, and how far out — with respect to Earth's orbit.

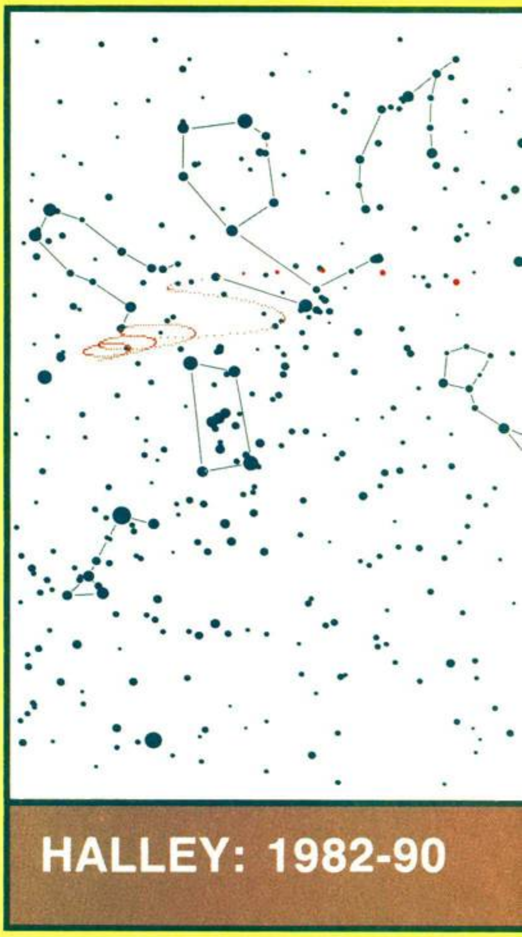
Then we determine where Earth is. This is simpler for Earth than it was for the comet, since our planet has a nearly circular orbit. Lines 860 and 870 contain the heliocentric longitude, H, and radius vector, R1. It is not necessary to find the distance above the ecliptic because Earth's orbit defines the ecliptic. Knowing where both bodies are in space, we proceed to compute the angles that define the direction Comet Halley will be seen from Earth. There are two cases: in the first, lines 940 through 970, the comet is nearer the Sun than Earth; lines 990 through 1020 treat the opposite case. This gives the ecliptic longitude, Q4; the ecliptic latitude, Q5, is found in lines 1060 through 1080.

The next routine converts ecliptic coordinates to equatorial coordinates. This calculation is carried out beginning with line 1120 and continues through 1360. As we have used epoch 1950 coordinates for the elements of the orbit, we get the answer in epoch 1950 coordinates. Finally, the program calculates the comet-to-Earth distance and estimates its magnitude. Since the comet will be more active after perihelion than before, the program uses different parameters in the magnitude equation.

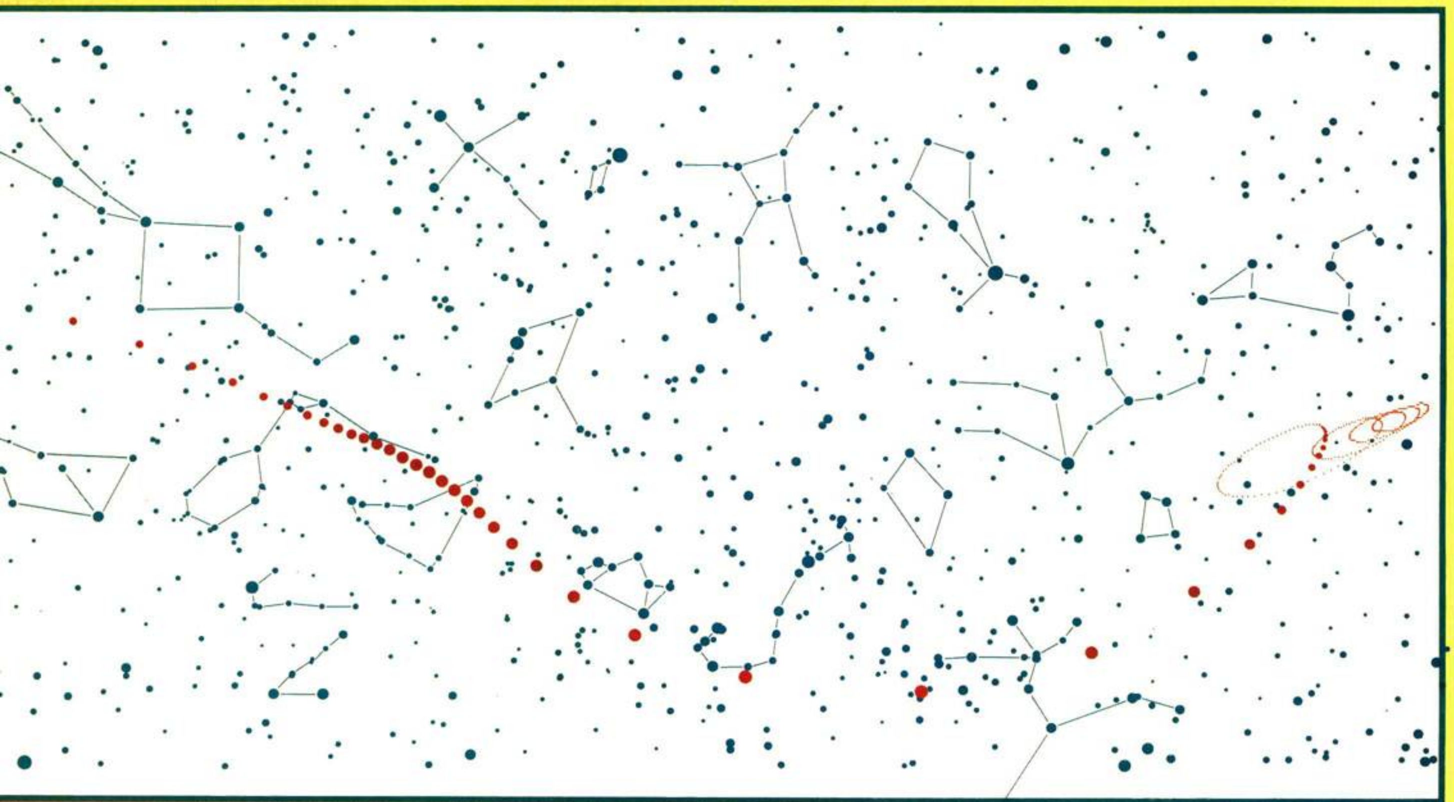
Finally, results are printed. Computing time from entering the date to seeing the results will range from 1 to 5 seconds, depending on how fast your computer runs. If your BASIC supports it, you may wish to declare all variables as double precision. The difference in the results, however, is smaller than other sources of error in this calculation.

As with any computer program, you must know your computer's BASIC well enough to spot and correct minor syntax differences. For more on computing comet orbits by this method, consult Duffett-Smith's book. *Halley's Comet* by Donald Tattersfield gives a more complete ephemeris program that also computes the altitude and azimuth of the comet for any date and latitude in 1985 or 1986. A somewhat more general approach is found in *Pocket Computer Programs for Astronomers* by Fred Klein — his program will run the orbit of *any* comet. If you own a Radio Shack pocket computer or wish to convert Klein's routines into your machine's BASIC, I recommend it.

Readers may download HALLEY.BAS from the CompuServe Public Access area. You can find it using the browse function and the keyword ASTRONOMY or read it directly by using this command line: R HALLEY.BAS[74206,110].

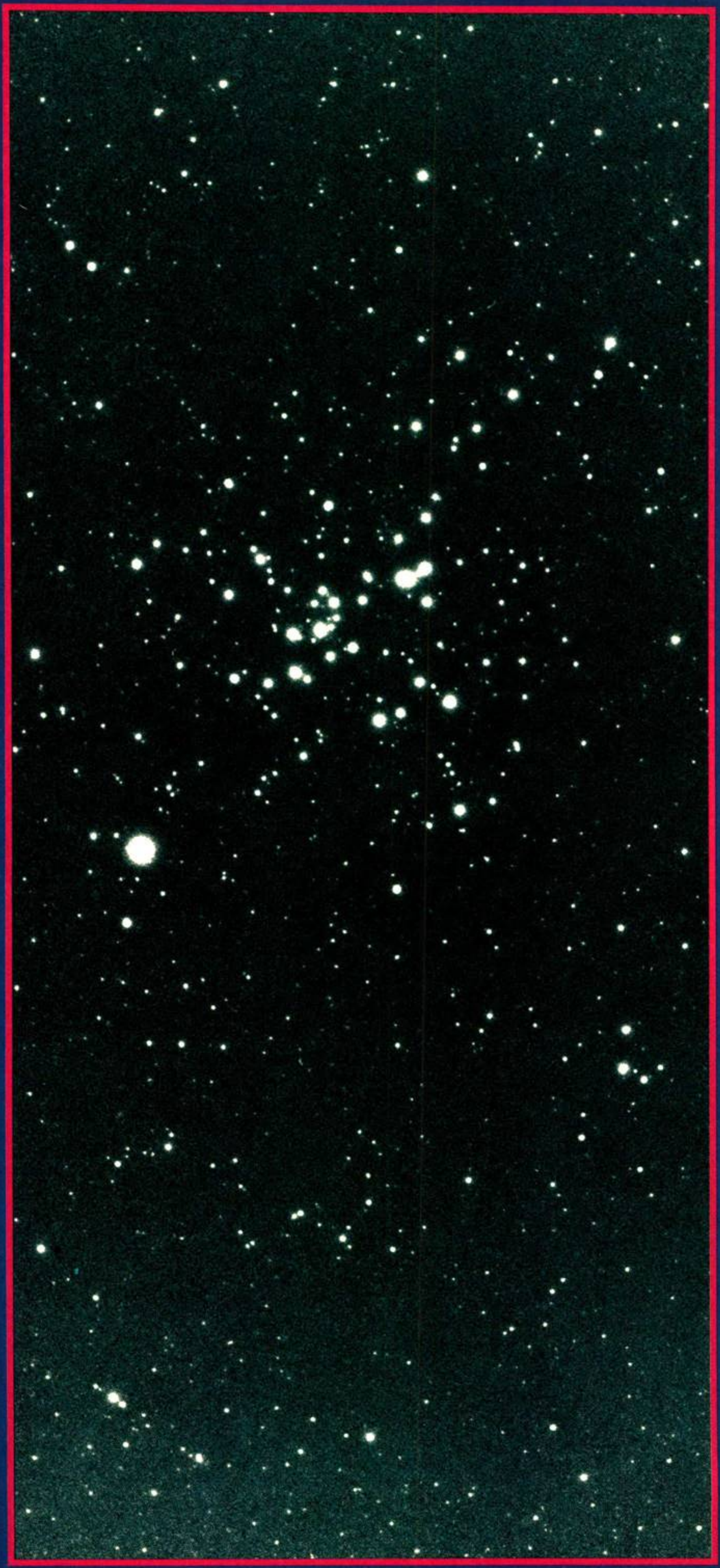


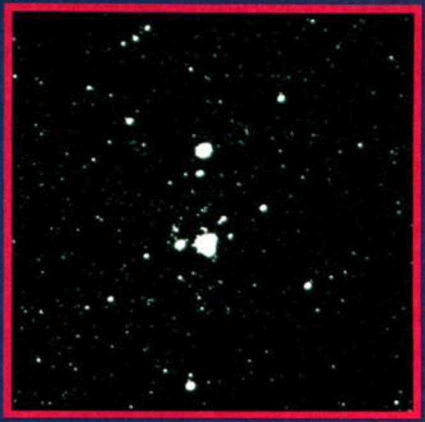
```
400 LET K=B
410 GOSUB 1930
420 LET B=(K*PI)/180
430 LET E=B
440 LET Y1=EO
450 LET Q=E-(Y1*SIN(E))-B
460 IF ABS(Q)<=.000017 THEN GOTO 500
470 LET U=Q/(1-(Y1*COS(E)))
480 LET E=E-U
490 GOTO 450
500 LET V=(SQR((1+Y1)/(1-Y1))*TAN(E/2))
510 LET V=2*ATN(V)
520 LET V1=(V*180)/PI
530 LET L=V1+PL
540 LET R=SM*(1-(Y1*Y1))/(1+Y1*COS(V))
550 LET F=L-AN
560 LET F2=IO
570 LET F1=(F*PI)/180
580 LET F2=(F2*PI)/180
590 LET I=(SIN(F1)*SIN(F2))
600 LET I=ATN(I/SQR(-I*I+1))
610 LET P=ATN(TAN(F1)*COS(F2))
620 LET P1=(P*180)/PI+AN
630 IF F>=90 AND F<=270 THEN P1=P1+180
640 IF P1<0 THEN LET P1=P1+360
650 LET P=(P1*PI)/180
660 LET R2=R*COS(I)
670 REM ----------------------------------
680 REM    Calculations for the Earth
690 REM ----------------------------------
700 LET X=1975
710 IF Y>=X THEN LET Z=1972
720 IF Y<X THEN LET Z=1976
730 IF Y>=X THEN LET S=0
740 IF Y<X THEN LET S=1
750 GOSUB 1780
760 LET T=(360/365.25)*(N/1.00004)
770 LET K=T
780 GOSUB 1930
790 LET T=K
800 LET T1=(T*PI)/180
810 LET C=.01672
820 LET J=T+(360/PI)*C*SIN(T1-.051943)
830 LET J=J+99.5343
840 IF J>360 THEN LET J=J-360
850 IF J<0 THEN LET J=J+360
860 LET H=((J-102.51044#)*PI)/180
870 LET R1=(1-C*C)/(1+C*COS(H))
880 REM ----------------------------------
890 REM  Compute Ecliptic Coordinates
900 REM ----------------------------------
910 LET U1=((P1-J)*PI)/180
920 LET U2=((J-P1)*PI)/180
930 IF R2<R1 THEN GOTO 990
940 LET Q1=(R1*SIN(U1))
950 LET Q1=Q1/(R2-(R1*COS(U1)))
960 LET Q1=ATN(Q1)
970 LET Q2=(Q1*180)/PI+P1
980 GOTO 1030
990 LET Q3=(R2*SIN(U2))
1000 LET Q3=Q3/(R1-(R2*COS(U2)))
1010 LET Q3=ATN(Q3)
1020 LET Q2=(Q3*180)/PI+J+180
1030 IF Q2>360 THEN LET Q2=Q2-360
1040 IF Q2<0 THEN LET Q2=Q2+360
1050 LET Q4=(Q2*PI)/180
1060 LET Q5=(R2*TAN(I)*SIN(Q4-F))
1070 LET Q5=Q5/(R1*SIN(U1))
1080 LET Q5=ATN(Q5)
1090 REM ---------------------------------
1100 REM  Convert To Equatorial Coords
1110 REM ---------------------------------
1120 LET E1=.40893064#
1130 LET L1=(SIN(Q5)*COS(E1))
1140 LET L1=L1+(COS(Q5)*SIN(E1)*SIN(Q4))
1150 LET M1=ATN(L1/SQR(-L1*L1+1))
1160 LET Y2=(M1*180)/PI
1170 LET B1=(TAN(Q4)*COS(E1))
1180 LET B1=B1-((TAN(Q5)*SIN(E1))/COS(Q4))
1190 LET G=ATN(B1)
1200 LET H1=(G*180)/PI
1210 LET I1=INT(Q2/90)
1220 LET J1=INT(H1/90)
1230 IF I1-J1=4 OR I1-J1=1 THEN H1=H1+360
```

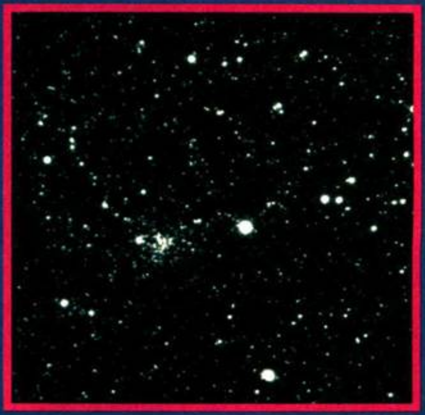


Approaching Earth (left), Halley describes a series of lazy loops, then swings around the sky, through perihelion in February 1986, then back into the depths of space (at right). The chart shows Halley's position every five days from the first day of 1982 through mid-August 1990.

```
1240 IF I1-J1=2 OR I1-J1=3 THEN H1=H1+180
1250 IF I1-J1=-4 THEN LET H1=H1+360
1260 IF I1-J1=-2 THEN LET H1=H1-180
1270 LET N1=H1/15
1280 LET W=INT((N1-INT(N1))*60+.5)
1290 IF W=60 THEN LET N1=N1+1
1300 IF W=60 THEN LET W=0
1310 LET K1=ABS(Y2)
1320 LET W1=INT((K1-INT(K1))*60+.5)
1330 IF W1=60 THEN LET G1=G1+1
1340 IF W1=60 THEN LET W1=0
1350 LET G1=INT(K1)
1360 IF Y2<0 AND G1<1 THEN LET W1=-W1
1370 LET D1=R1*R1+R2*R2
1380 LET D1=D1-(2*R1*R2*COS(U1))
1390 LET D2=SQR(D1)
1400 LET R3=D2/COS(I)
1410 LET K9=R
1420 GOSUB 2040
1430 LET R=K9
1440 LET K9=R3/10
1450 GOSUB 2040
1460 LET R3=K9*10
1470 LET MO=4.1:LET N=3.1
1480 IF DS<0 THEN MO=5:N=4.44
1490 LET MA=MO+5*.4343*LOG(R3)
1500 LET MA=MA+N*2.5*.4343*LOG(R)
1510 LET MA=(INT(10*MA))/10
1520 IF Y2<0 THEN LET G1=-G1
1530 REM --------------------------------
1540 REM      Print Ephemeris For Date
1550 REM --------------------------------
1560 PRINT "----------------------------"
1570 PRINT "DATA FOR "+CO$
1580 PRINT "DATE: M/D/Y=";M;"/";D;"/";Y
1590 PRINT "DAYS TO PERIHELION ";INT(DS)
1600 PRINT
1610 PRINT "COORDINATES:"
1620 PRINT " RA:"; INT(N1);"HRS";W;"MIN"
1630 PRINT "DEC:"; G1;"DEG";W1;"MIN"
1640 PRINT
1650 PRINT "DISTANCES:"
1660 PRINT " COMET TO SUN"; R;"AU"
1670 PRINT "COMET TO EARTH";R3;"AU"
1680 PRINT
1690 PRINT "PREDICTED MAG";MA
1700 PRINT "---------------------------"
1710 PRINT "PRESS 0 FOR ANOTHER DATE"
1720 IF INKEY$="0" THEN GOTO 1740
1730 GOTO 1720
1740 PRINT
1750 GOTO 200
1760 REM --------------------------------
1770 REM  Subroutine: DAYS TO PERIHELION
1780 LET A=(Y-Z)/4
1790 LET A1=INT(A+S)
1800 LET N=365*(Y-X+S)+A1
1810 IF INT(A)<>A THEN GOTO 1830
1820 IF (M=2 AND D<29) OR M=1 THEN N=N-1
1830 IF M>2 THEN GOTO 1870
1840 LET M2=M-1
1850 LET M2=31*M2
1860 GOTO 1890
1870 LET M2=M+1
1880 LET M2=INT(30.6*M2)-63
1890 LET N=N+M2+D-365*S
1900 RETURN
1910 REM --------------------------------
1920 REM: PLACE BETWEEN 0 AND 360 DEG
1930 IF K<0 THEN GOTO 1950
1940 IF K>360 THEN GOTO 1980
1950 LET K=K+360
1960 IF K>=0 THEN GOTO 2010
1970 GOTO 1950
1980 LET K=K-360
1990 IF K<=360 THEN GOTO 2010
2000 GOTO 1980
2010 RETURN
2020 REM --------------------------------
2030 REM: ROUND OFF SUBROUTINE
2040 LET K9=K9*1000
2050 LET K9=INT(K9+.5)
2060 LET K9=K9/1000
2070 RETURN
```



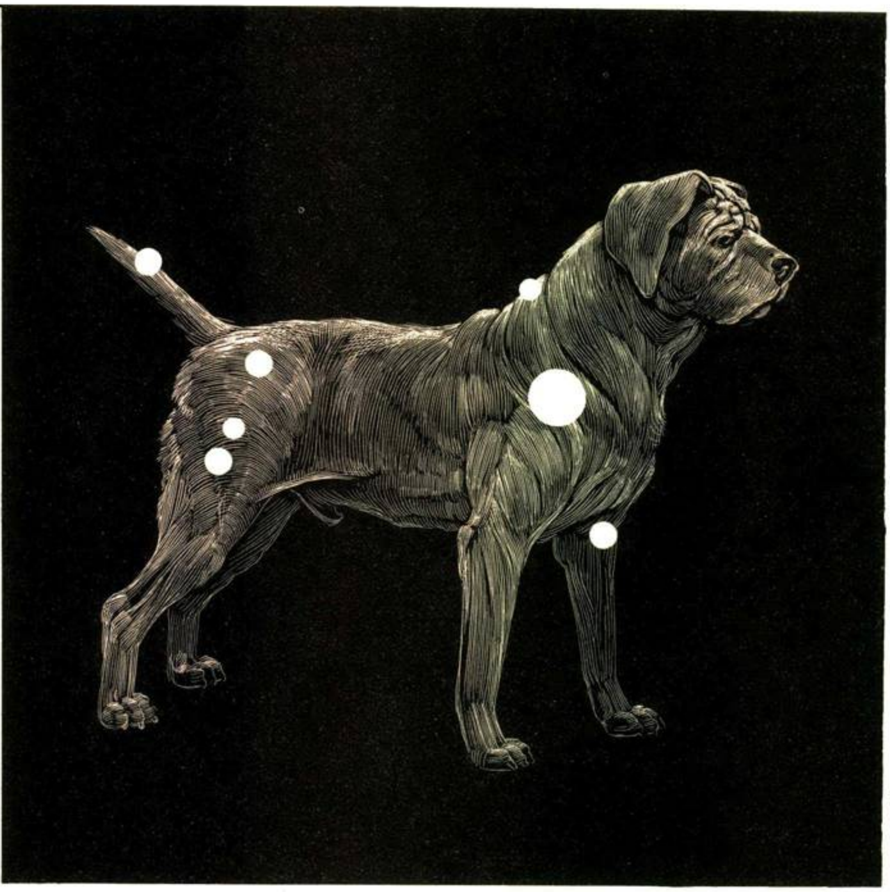




Left: The great cluster M-41, lying some 4° south of Sirius, spans a Moon's diameter and shines at fifth magnitude. It is one of the sky's grandest open clusters for binoculars and small telescopes. Photo by Tom Dessert. Top: The bright, compact cluster NGC-2362 surrounds the star Tau (τ) Canis Majoris. In the same field — to the north — is the eclipsing binary UW CMa. Lick Observatory photo. Above: The rich open cluster NGC-2360 contains many stars of 9th magnitude and fainter. Lick Observatory photo.

Canis Major

CMa
Canis Majoris



Keith Ward

The brilliant constellation **Canis Major**, the Large Dog, is one of the most easily-recognized winter groups of stars. It is renowned for containing Sirius, the brightest star in the sky. Even so, Canis Major doesn't contain much variety when it comes to deep-sky objects. But those it does contain are worthy of slow, careful observing: a number of bright and impressive open clusters, a couple of complex nebulosities, a difficult planetary nebula, and two galaxies heavily obscured by the Milky Way's thick blanket of dust.

Sirius (Alpha [α] Canis Majoris) is not one of the Galaxy's most luminous stars, but appears as the brightest because it is the fifth closest at 2.7 parsecs. Sirius is an A1-type main sequence star. It shines with the light of 23 Suns, measures 1.8 solar diameters across, and contains nearly 2½ times the Sun's mass. Its apparent magnitude is −1.4, so only Venus, Jupiter, Saturn, and Mars can outshine it in the sky. As you stand under the stars and gaze up at Sirius, realize that it is over half a million times farther away than our Sun.

Sirius is also known as the Dog Star, and gains much attention from double star observers because of its faint, elusive companion. Sirius B, the "Pup," was suspected as early as 1834 by the German astronomer F.W. Bessel and discovered visually by Alvan G. Clark in 1862. Sirius B is a prime example of a white dwarf star — a tiny, incredibly dense object only about 30,000 kilometers across. A cubic inch of this star weighs over 2½ tons! This remarkable state results from the star running out of hydrogen fuel to burn, collapsing upon itself, and shining only because its temperature remains high. Such stars are "dead" and will eventually become dark as they cool off.

Because it is so much fainter than Sirius, the Pup is difficult to observe in backyard telescopes. It shines at magnitude 8.7, but at present lies only 9″ away from Sirius in p.a. 72°. (Its period is about 50 years; it will close to 3½″ during the 1990s.) The glare from Sirius is usually overpowering, but you may spot the companion by moving Sirius slightly out of your field of view or placing an occulting bar over the bright star's image in the eyepiece (try using a paper clip painted flat black). If you spot the Pup, you'll be among a relatively select group of backyard astronomers.

Of Canis Major's many open clusters, **Messier 41** (NGC-2287) easily stands out as the finest. It lies about 4° south of Sirius and is easily found in 7x50 binoculars or finder telescopes. M-41 measures 32′ across and shines with the light of a fifth magnitude star.

Through the telescope, M-41 fills a low-power field with shimmering stars. At higher powers, the cluster appearance becomes lost and individual star colors are more easily detectable. A 3-inch scope shows 40 or 50 stars, while an 8-inch or bigger instrument reveals a multitude of additional fainter stars painted across the background.

M-41 holds some 100 stars, the brightest being seventh-magnitude objects. The very brightest are G- and K-type giants, followed by many bright blue B-type giants with high intrinsic luminosities. M-41 lies about 750 parsecs away and has a density of 1.1 stars per cubic parsec.

Two fine open clusters lie in the Dog's hindquarters — **NGC-2354** and **NGC-2362**. The former is nearly as large as M-41, but is composed of 60 faint stars in a loose arrangement. Again, use low powers when gazing at this object. NGC-2362 is a small group of 40 stars, which surrounds the bright star Tau (τ) Canis Majoris. It measures only 6′ across, but is unusually attractive. With a finderscope, it appears as an unresolved haze blanketing fourth-magnitude Tau. A 2-inch or larger scope resolves the cluster, showing two dozen stars of seventh-magnitude and fainter. Larger telescopes show all 40 stars and make NGC-2362 satisfying viewing.

NGC-2362 is one of the youngest known open clusters, probably less than one million years old. On the H-R diagram, the cluster's stars are displaced to the right of the normal main sequence, which suggests they have not finished contracting. (Other very young clusters are NGC-2264 in Monoceros and the Double Cluster in Perseus.) NGC-2362 lies about 1.4 kiloparsecs away, with its brightest stars O- and B-type giants. As viewed from this group, our Sun shines at a mere magnitude of 15.5. Tau itself may be a member also, but if it is, it's one of the most luminous supergiants known.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Assumed to be at the cluster's distance, Tau would outshine the Sun by 50,000 times!

Undoubtedly one of the most massive and luminous stars known is the odd variable **UW Canis Majoris**, which lies only 24′ north of NGC-2362. UW CMa is an eclipsing binary consisting of two stars that orbit each other in just 4.4 days. The distance between the stars, both of which are flattened into ellipsoids by the mutual tug of gravity, is 17 million miles — around 0.2 astronomical unit. The distance to this pair is about 1.0 kiloparsec, making the system's luminosity 16,000 times that of the Sun. With a short period and small magnitude range (4.7 to 5.0), detecting light variations in this system is difficult with backyard telescopes.

Canis Major contains three nebulae observable in small telescopes. **NGC-2359**, along with its fainter partner **IC 468**, presents a dim and challenging region of emission nebulosity. Both nebulae are illuminated by a magnitude 10.4 star. Shaped like a twisted comet and measuring 10′ x 5′, NGC-2359 appears as a faint streamer of pale grey light in an 8-inch scope. A 16-inch telescope shows irregular lighter and darker patches across its surface, but not much detail due to a low surface brightness. IC 468, adjacent to 2359, measures 20′ across and on dark nights shows up as a pale circle of weak light.

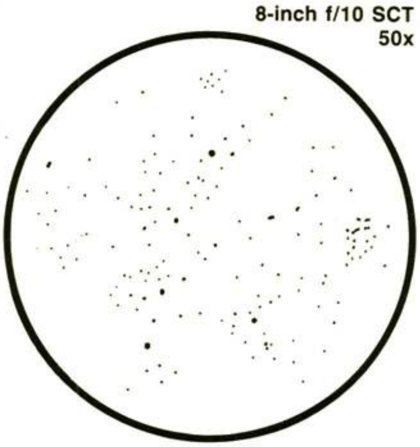
Difficult to find but worth pursuing is the tiny planetary nebula **IC 2165**, which is located in the northwest corner of the constellation. At magnitude 12.5, this nebula is bright enough to see with a 4- or 5-inch telescope, but measures only 8″ across. At low powers, it appears nearly stellar and is hard to pick out from the Milky Way's rich background. Once you've determined IC 2165's approximate position, crank up the magnification and look for a slightly bluish, fuzzy "star."

Canis Major contains several more bright open clusters, three of which lie in the northeastern reaches near M-46 and M-47 in Puppis. These are **NGC-2360**, **NGC-2374**, and **NGC-2383**. NGC-2360 is a rich group of 50 stars up to ninth-magnitude packed into a 10′ diameter. Found about 3½° east of Gamma (γ) Canis Majoris, it is one cluster that handles higher magnifications quite well. Nearby and equally commanding is NGC-2374, which measures 15′ across and contains many widely-scattered bright stars. Lying to the south is NGC-2385 — a faint yet very rich group measuring only 2′ in diameter. On crisp, clear nights, use high magnifications and a 6-inch or larger scope to partially resolve this tight bunch of 50 stars, which at 12th magnitude and fainter appear as tiny specks of light.

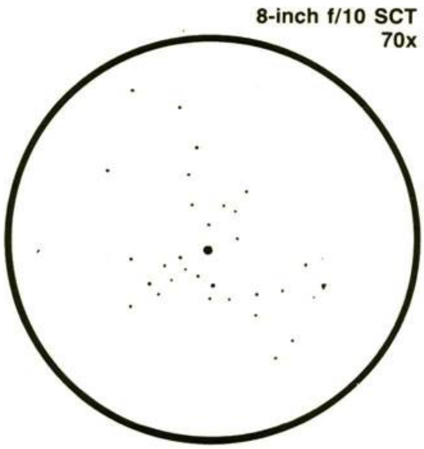
Two final clusters are **NGC-2204** and **NGC-2243**. NGC-2204 is a large, unimpressive collection of 20 indistinct stars covering 10′ of sky. If it were alone in the middle of nowhere, this cluster would stand out better than it actually does — surrounded by brighter cousins in the rich starfields of Canis Major. NGC-2243 is a small, fairly rich group; its 50 constituent stars shine rather dimly in a 4′ circle.

Observing in the winter Milky Way, you wouldn't expect to find galaxies because the region is dominated by obscuring dust. Yet **NGC-2207** and **NGC-2217** — two 12th magnitude objects — are routinely visible in 6-inch scopes. NGC-2207 is a complex system measuring 2.5′ x 1.5′ across, and is perhaps a double galaxy or an interacting pair. NGC-2217 is a run-of-the-mill type-SBa barred spiral covering an area 4.0′ x 3.0′. On dark, crisp nights an 8-inch telescope shows it as a dim, even halo of light surrounding a sharply brighter, highly-condensed core.

M-41


8-inch f/10 SCT
50x

NGC-2362

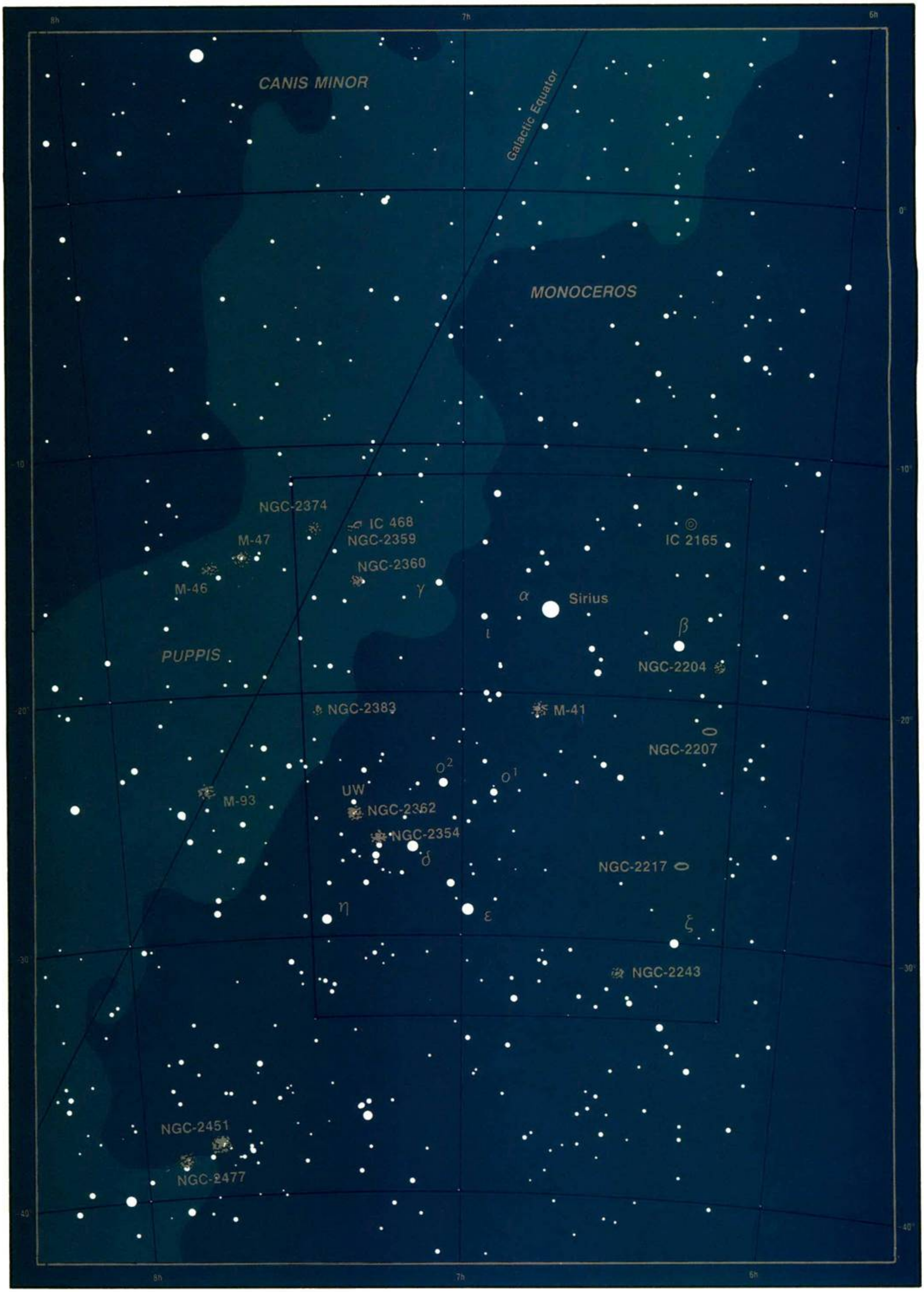

8-inch f/10 SCT
70x

Sketches by David J. Eicher

Object	M#	Type	R.A. (2000) Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
NGC-2204		⊙	6h 15.7m −18°36′	9.6	10′	30	11....
NGC-2207		§	6h 16.4m −21°22′	12.3	2.5′x1.5′		
NGC-2217		§B	6h 20.8m −27°15′	12.0	4.0′x3.0′		
IC 2165		■	6h 21.9m −12°59′	12.5	8″		
NGC-2243		⊙	6h 29.5m −31°17′	—	4′	50	
Sirius (α CMa)		★^{2}	6h 45.2m −16°42′	−1.4, 8.7	9″		
NGC-2278	M-41	⊙	6h 47.0m −20°45′	5.0	30′	55	7....
NGC-2354		⊙	7h 14.2m −25°43′	—	25′	60	
IC 468		☐E	7h 17.5m −13°10′	—	20′		10.4
NGC-2360		⊙	7h 17.6m −15°38′	9.1	10′	50	9....
NGC-2359		☐E	7h 17.7m −13°12′	—	10′x5′		10.4
UW		EV	7h 18.7m −24°34′	4.7↔5.0	4.4d		
NGC-2362		⊙	7h 18.7m −24°58′	3.9	3′	240	4....
NGC 2374		⊙	7h 24.1m −13°15′	—	15′		
NGC-2383		⊙	7h 24.8m −20°56′	8.8	2′	50	12....

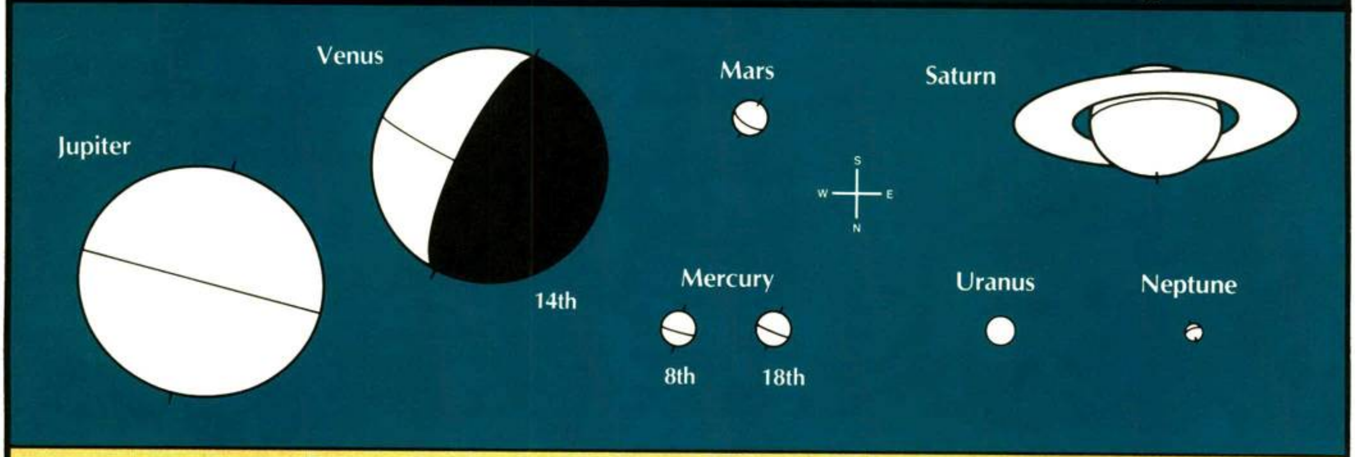
N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.

★^{2}	*Double Star*
EV	*Eclipsing Variable*
⊙	*Open Star Cluster*
■	*Planetary Nebula*
☐E	*Emission Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*


8h
7h
6h
CANIS MINOR
Galactic Equator
0°
MONOCEROS
-10°
NGC-2374
IC 468
NGC-2359
M-47
IC 2165
NGC-2360
M-46
γ
α
Sirius
β
ι
PUPPIS
NGC-2204
-20°
NGC-2383
M-41
NGC-2207
o2
o1
UW
M-93
NGC-2362
NGC-2354
δ
NGC-2217
η
ε
ζ
-30°
NGC-2243
NGC-2451
NGC-2477
-40°
8h
7h
6h

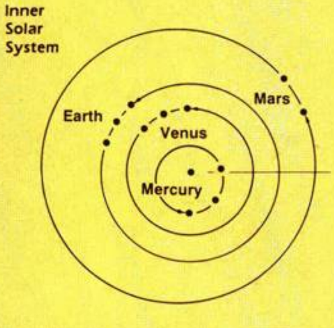
Planetary Data

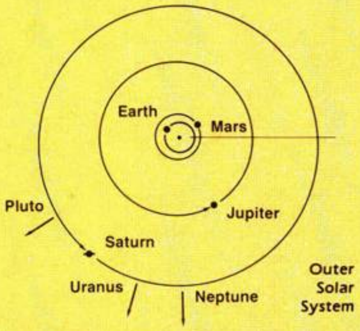
February 1985


Venus
Jupiter
14th
Mars
Saturn
S
W
E
N
Mercury
8th
18th
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.99	—	—	312°05.0′	20h 59.0m	−17°07.1′
		14	−26.8	32.4′	—	0.99	—	—	325°14.9′	21h 50.9m	−13°02.4′
		28	−26.8	32.3′	—	0.99	—	—	339°21.4′	22h 44.5m	−7°59.3′
Mercury	☿	1	−0.5	4.9″	94%	1.37	0.46	271°46.3′	299°42.6′	20h 09.0m	−21°48.8′
		14	−1.2	4.8″	99%	1.40	0.42	311°18.3′	321°17.6′	21h 37.5m	−16°23.0′
		28	−1.4	5.2″	96%	1.30	0.34	9°09.1′	347°05.0′	23h 14.3m	−6°10.7′
Venus	♀	1	−4.5	27.2″	46%	0.61	0.72	93°40.1′	358°57.2′	23h 54.3m	0°39.4′
		14	−4.6	32.1″	37%	0.52	0.72	114°43.6′	10°07.1′	0h 32.6m	6°40.8′
		28	−4.6	39.5″	26%	0.42	0.72	137°28.0′	19°01.7′	1h 02.4m	12°07.3′
Mars	♂	14	1.2	4.7″	94%	2.00	1.44	36°23.5′	8°39.7′	0h 32.3m	3°09.5′
Jupiter	♃	14	−1.9	32.7″	100%	6.03	5.14	297°16.5′	301°52.2′	20h 16.8m	−20°03.6′
Saturn	♄	14	0.5	16.7″	100%	9.91	9.92	232°01.5′	237°56.8′	15h 44.8m	−17°34.4′
Uranus	⛢	14	5.7	3.6″	100%	19.41	19.06	254°38.7′	257°36.1′	17h 06.1m	−22°52.4′
Neptune	♆	14	8.0	2.2″	100%	30.85	30.26	271°28.0′	273°08.8′	18h 13.6m	−22°17.1′
Pluto	♇	14	13.7	0.1″	100%	29.44	29.78	212°52.4′	215°04.2′	14h 33.6m	2°50.0′

Inner
Solar
System

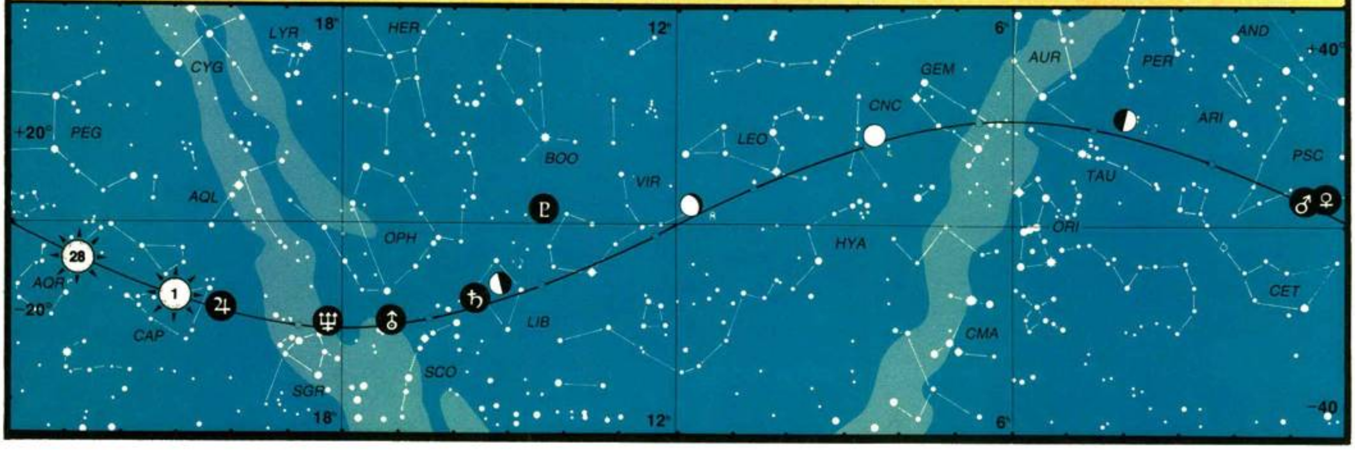

Earth
Mars
Venus
Mercury


Earth
Mars
Pluto
Jupiter
Saturn
Uranus
Neptune

Outer
Solar
System

Moon Data

Full Moon.........February 5 at 15h19m
Last Quarter.......February 12 at 7h57m
New Moon........February 19 at 18h43m
First Quarter.......February 27 at 23h41m
Full Moon...........March 7 at 2h13m
Last Quarter.........March 13 at 17h34m
Apogee: Feb. 8 at 3h31m...364,272 km.
Perigee: Feb. 24 at 3h57m...405,509 km.


LYR
18h
HER
12h
6h
AUR
AND
+40°
CYG
GEM
PER
CNC
+20°
PEG
LEO
ARI
BOO
PSC
TAU
VIR
♂ ♀
AQL
♇
ORI
OPH
HYA
28
AQR
−20°
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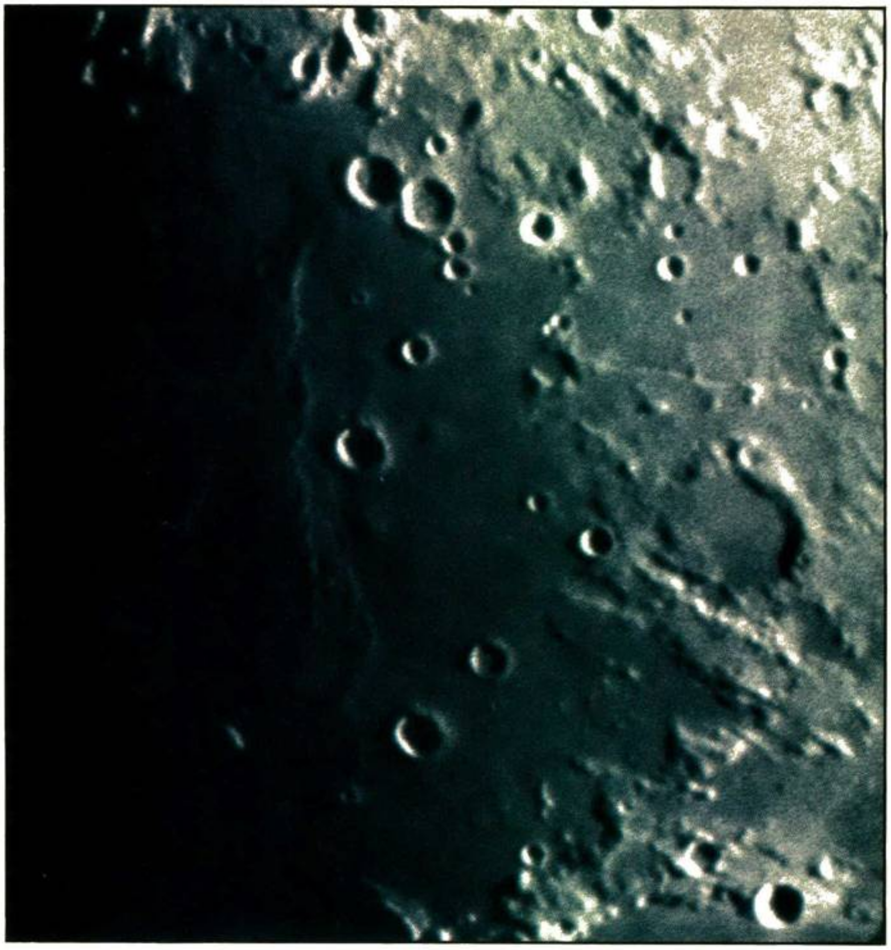
♄
LIB
♆
⛢
CAP
CMA
SCO
SGR
18h
12h
6h
−40



Sunset on Mare Tranquillitatis brings out the wrinkle ridges of the ruined crater Lamont, left center. Photo by Bill Wilkinson, who used a 6-inch Maksutov, Tri-X, and a 1-second exposure at about f/70.

Mercury

At superior conjunction last month, Mercury is out of sight during February.

Venus

Dominating the evening sky, Venus reaches greatest brilliance on February 26th, when several factors make this planet the brightest thing in the sky apart from the Sun and Moon. As it nears inferior conjunction, we see more of the night-side of Venus and less of its sunlit cloudtops — which tends to reduce its brightness. At the same time, the planet is getting closer and its apparent size is steadily growing — adding to its brightness. On the 26th, these effects combine and Venus blazes forth at its maximum −4.6 magnitude.

In your telescope, Venus will be a large crescent that is almost painfully bright to observe at low power during full darkness. Therefore try observing before twilight darkens the sky too much, when the reduced contrast is easier on the eye.

Mars

The companion of Venus in the evening sky, Mars is distinctly inferior in brightness and apparent size. Venus passes Mars in right ascension twice this month (on the 8th and 15th); the separations will be 2.7° (8th) and 3.8° (15th), with Venus north of Mars both times. Besides these conjunctions, Venus and Mars will stay within a binocular (or very-low-magnification telescopic) field of view for much of the month. Unfortunately, Mars has only about a sixth the apparent size of Venus. This means that at lowest power (to pair them in the field of view), Mars will be a featureless tawny "dot."

Asteroids

1 Ceres (magnitude 8.2) is moving eastward in Aries. Its positions:

10th: 2h 59m 37s, 14° 24.5′
20th: 3h 08m 57s, 15° 35.3′

Ceres sets at midnight local time on the 15th.

2 Pallas (9.9) lies near the joint borders of Pisces, Cetus, and Aquarius. Its positions:

10th: 23h 53m 41s, −8° 18.8′
20th: 0h 07m 33s, −7° 32.2′

Pallas sets around 8 p.m. local time at mid-month.

3 Juno (9.9) is moving eastward, just southeast of the star Gamma (γ) Virginis. Its positions:

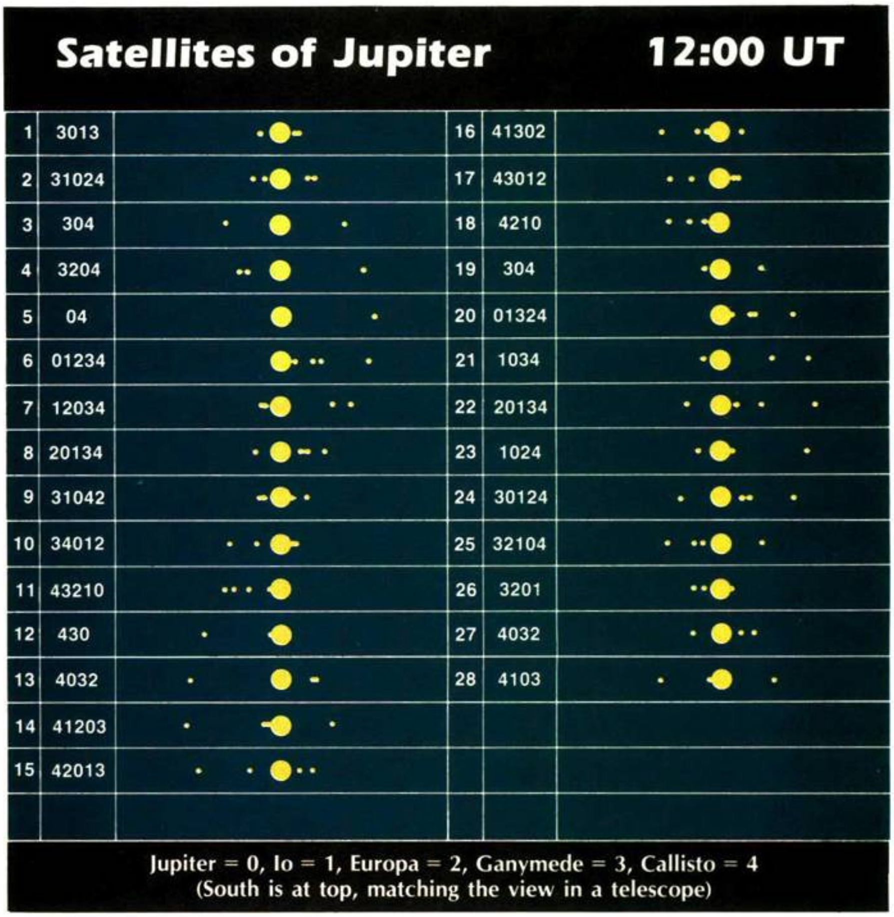
10th: 12h 51m 39s, −3° 15.0′
20th: 12h 49m 09s, −2° 14.4′

Juno rises about 10:30 p.m. local time on the 15th.

4 Vesta (7.0) lies in eastern Virgo. Its positions:

10th: 14h 15m 22s, −3° 49.2′
20th: 14h 22m 01s, −3° 40.6′

Vesta rises around 11:30 p.m. local time at mid-month.



Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

This month's "Best Astro-Photo" Award goes to Brad Wallis and Robert Provin for their fine photograph of the Pleiades. Provin and Wallis used a 6-inch, 103a-O film, and a 30-minute exposure at f/6.

For convenience in plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

Though Jupiter has returned for viewing in the morning sky (conjunction was on January 14th), it is now in Capricornus, a relatively barren piece of sky offering few conjunctions with deep-sky objects — unlike Sagittarius last observing season. In addition, its low elevation renders it barely "telescope-worthy" this month.

Saturn

Saturn is now past the meridian by sunrise, making it an easy object for early risers to view. The rings spread 38" across, somewhat more than Jupiter's equatorial diameter; Saturn itself has an equatorial diameter of 16.7".

Uranus

Uranus lies in southern Ophiuchus. The finder chart on page 83 of last month's issue shows its location relative to Theta (θ) and Xi (ξ) Ophiuchi, two nearby third- and fourth-magnitude stars. On February 15th, 45 minutes before sunrise, Uranus is 25° high in the south-southeast. It is 3.6" across and at magnitude 5.7.

Neptune

Neptune is in Sagittarius between M-20 (the Trifid Nebula) and Mu (μ) Sagittarii, a fourth-magnitude star (see the finder chart on page 83, January issue). It has a 2.2" disk and is at 8.0 magnitude. On the 15th, it will be 20° high in the southeast 45 minutes before sunrise.

Meteors

February has no outstanding meteor showers, but two minor ones are of interest.

Peaking in activity on February 5th, the Alpha Aurigid shower produces about 10 to 15 meteors an hour. But moonlight will be a problem this year, since Full Moon is also on the 5th. The radiant, as the shower's name tips you off, lies near Capella in Auriga.

Later in the month (around the 25th), there is a very sparse shower — the Delta Leonids — that comes from Leo's hindquarters. The (idealized) zenithal hourly rate for this shower is only 3, but at least the Moon is near First Quarter and will set by midnight.

Comet Halley

During February, P/Halley is in northern Orion and moving westward toward Orion's raised shield-arm (also see Photography in Astronomy, page 35, and Gazer's Gazette, page 75). The comet's positions (epoch 2000.0 coordinates) are:

10th: 5h 09m 27s, 12° 58.9'
20th: 5h 03m 08s, 13° 19.8'

On the 15th, the comet is 4.4 Astronomical Units from Earth and has a predicted magnitude of 16.3.

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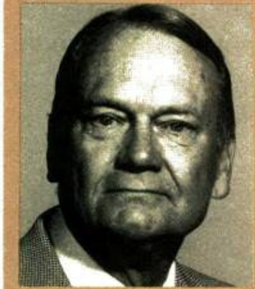

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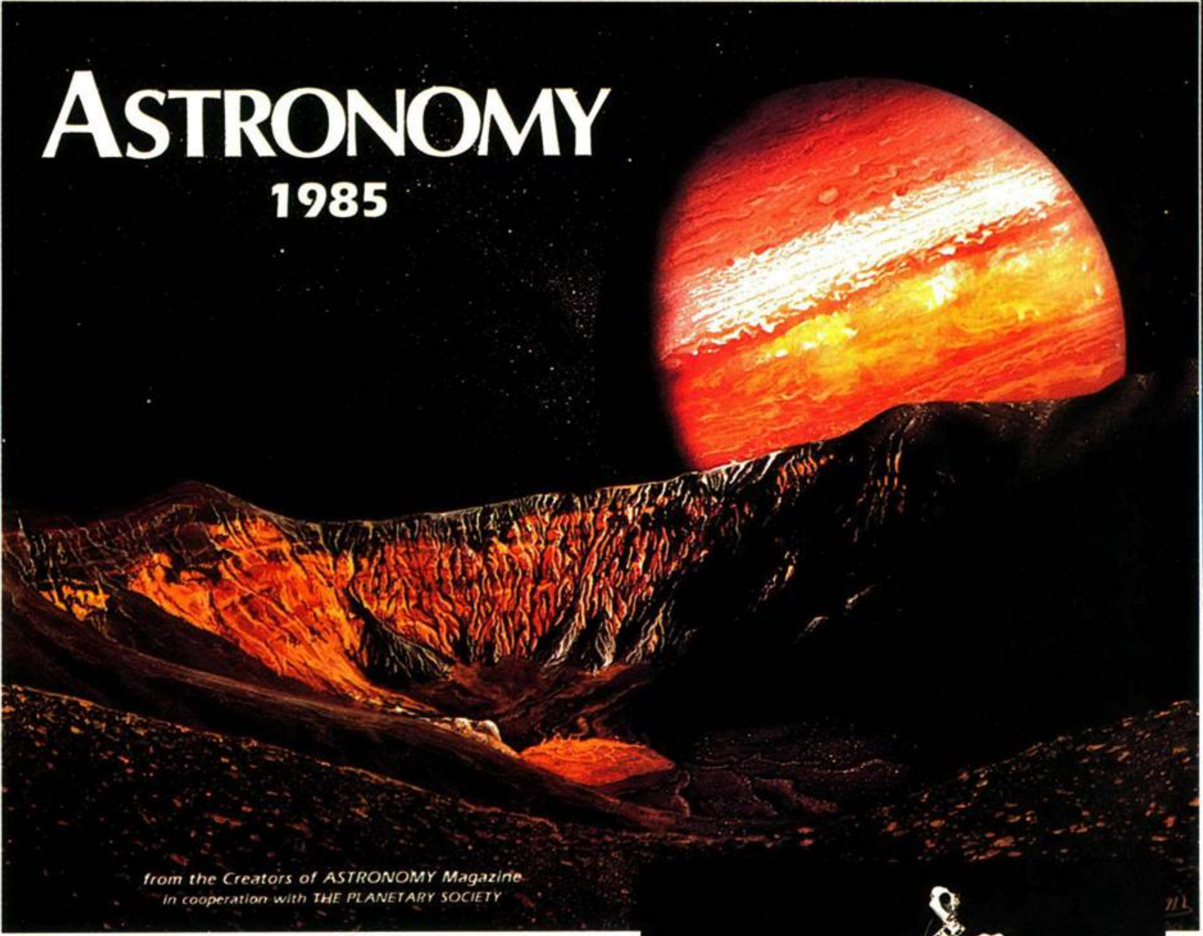
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